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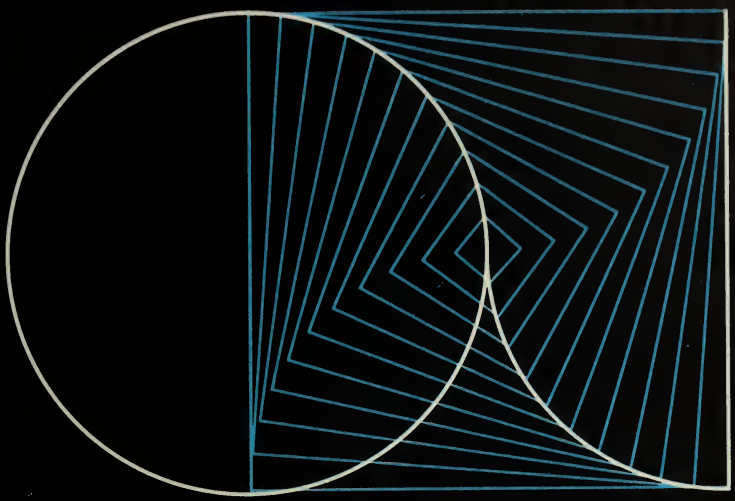

GRADUATE STUDY AND RESEARCH IN CIVIL AND SANITARY ENGINEERING

UNIVERSITY OF ILLINOIS BULLETIN OCTOBER 1, 1964

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GRADUATE STUDY AND RESEARCH

OCTOBER 1, 1964

IN CIVIL AND SANITARY ENGINEERING

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Introduction

The Department of Civil Engineering at the University of Illinois offers challenging opportunities to qualified students working towards advanced degrees. Formal course work and participation in creative research enable the civil engineer with graduate training to go beyond the normal limitations imposed by the baccalaureate degree and to be better prepared to contribute to the progress of his profession. The department graduate program places special emphasis on research training in the belief that this is one of the most valuable kinds of scientific engineering experience and training which can be gained by the student.

Recent scientific and industrial developments and the increasing complexity of many phases of engineering have created a strong demand for civil and sanitary engineers with formal study beyond that offered in undergraduate programs. Among the fields of work for which graduate study is desirable and for which it prepares the engineer are: advanced analysis and design; consulting engineering practice; teaching of both fundamental and advanced courses in civil engineering, mechanics, and related fields; research and development in industrial laboratories, educational and scientific institutions, and governmental laboratories; and administrative responsibilities in various specialized fields.

This bulletin contains essential information for those considering graduate study in civil engineering and sanitary engineering. It is recognized that some of the brief statements may generate questions. Students are encour-

aged to correspond with the Head of the Department on specific problems or questions. Address inquiries to:

Head, Department of Civil Engineering
205 Civil Engineering Hall
University of Illinois
Urbana, Illinois 61803

Advanced study, research, and professional training are offered in the following general fields of civil and sanitary engineering:

Air Pollution
Analysis and Design of Structures
Behavior of Structures and Properties of Structural Materials (Concrete, Steel, etc.)
Construction Engineering and Management
Digital Computer Applications to Analysis or Design
Highways and Transportation
Hydrology and Water Resources
Hydromechanics and Hydraulic Structures
Models Research
Photogrammetry and Photo-interpretation
Radiological Health
Rock Mechanics
Soil Mechanics and Foundations
Structural Dynamics: Design for Earthquake, Shock, and Blast Excitation
Structural Mechanics
Surveying and Geodetic Engineering
Systems Engineering
Traffic Engineering
Urban Planning and Management
Waste Water Treatment
Water Quality and Treatment

Because of the extensive research programs directed by members of the staff in these and in related fields, excellent facilities for research are available for use by graduate students.

The degrees of Master of Science and Doctor of Philosophy may be attained by qualified students who satisfy the requirements of the department and the Graduate College. Progress toward an advanced degree is measured not only by the accumulation of units of credit in formal course work but also by evidence of intellectual growth and achievement.

The main purpose of graduate study is to enable a student to broaden his knowledge of, and increase his competence in, a given field. Graduate study, especially in the second and third years of the doctorate, aims at the development of independent scholarship, originality, and competence in research, coupled with development of engineering judgment. Training of this type is fostered by close and frequent contact between the student and academic staff. The students' advisers in research and graduate studies in

civil engineering are among the most eminent engineering teachers in the country. Because almost all staff members are directly involved in research, and are advisers to a relatively small number of students, close individual contact exists.

Approximately 280 students from all parts of the world are enrolled in the graduate programs. Because of the large enrollment and the stature of the department, it is possible to offer a wide range of courses on all phases of civil and sanitary engineering. Graduate students in civil engineering at the University of Illinois are selected from the top men in the United States and foreign countries. The many native and foreign students contribute to the department a variety of experience which broadens the outlook of all who are included in the graduate group. The knowledge and friendship gained from contact with this select group will be of importance and advantage to the student in his future career.

The staff, graduate students, and technicians in the Department of Civil Engineering are shown statistically as of June, 1964:

Full Professors	30	Graduate Students, including research assistants and fellows	280
Associate Professors	15		
Assistant Professors	20	Technicians and Student Employees	42
Instructors	11		
Post-doctoral Fellows	2	Secretaries and Others	35

Degrees Awarded:	*1961-62*	*1962-63*	*1963-64*
M.S.	81	98	113
Ph.D.	28	19	42

Extensive research programs, involving an annual expenditure of almost two million dollars, enable students to participate in active research projects. Research is supported by the University as a part of its educational program for advanced undergraduate and graduate students. However, a large part of the research and graduate program is supported by special grants from various sponsors, including federal and state agencies, technical societies, professional associations, and research councils. Present sponsors include:

American Iron and Steel Institute
Automotive Safety Foundation
Canadian Institute of Steel Construction
Champaign-Urbana Sanitary District
Chicago Bridge and Iron Foundation
Defense Atomic Support Agency
Department of the Air Force: Weapons Laboratory
Department of the Army: Corps of Engineers; Waterways Experiment Station
Department of Commerce: Bureau of Public Roads
Department of Defense: Office of Civil Defense
Department of Health, Education, and Welfare: Public Health Service

Department of the Navy: Bureau of Ships; Bureau of Yards and Docks; Office of Naval Research
Engineering Foundation
Industrial Fasteners Institute
Metropolitan Sanitary District of Greater Chicago
National Academy of Science-National Research Council: Ship Structure Committee; Highway Research Board
National Lime Association
National Science Foundation
National Steel Corporation
Portland Cement Association
Raymond Concrete Pile Company
Research Council on Riveted and Bolted Structural Joints
State of Illinois: Division of Highways; Department of Conservation
United States Steel Corporation
Welding Research Council

Admission

Applications for admission are processed by the Dean of Admissions and Records. Application forms for United States students can be obtained from the Graduate College, the Office of Admissions and Records, or the Department of Civil Engineering. Students should request, if needed, a copy of the Graduate College catalog and the pamphlet entitled *The Road to Graduate School* when the application forms are requested. In order to avoid delays, a prospective student is urged to submit his application at least three months in advance of the opening of the session in which he plans to enroll.[1] Students from a country other than the United States should make application by letter in accordance with instructions given below. A student whose native language is not English should submit his application at least three months (preferably five months) prior to the anticipated registration date. An official transcript from each undergraduate college attended must be forwarded. In addition, all graduate students entering the Department of Civil Engineering must arrange to have one additional set of transcripts forwarded to the department office for its records and use. Transcripts of students who enter the Graduate College can not be returned. An official statement of rank in class, and rank in college, also should be submitted.

The general requirements governing admission are as follows:

Admission to the Graduate College with full status in civil or sanitary engineering is granted to graduates of institutions whose requirements for the bachelor's degree are substantially equivalent to those of the University of Illinois, provided the applicant's preparation is appropriate to advanced

[1] For approximate enrollment dates, see page 13, Registration and Program of Studies. Students applying for financial assistance see page 22.

study in his chosen major field and his scholastic average is at least 4.0.[1] This average is computed on the basis of the last sixty semester hours, or 110 quarter hours, of credit recorded.[2] In computing grade-point averages, evidence that the school's grading system is based on a different datum is considered. Under certain conditions applicants with a grade-point average of less than 4.0, and applicants from schools with different grading systems, may be considered if their average is at least the equivalent of 3.75 and evidence is submitted indicating that the applicant's ability is not appropriately measured by the grades submitted. Such applicants should have their application accompanied by at least two letters of recommendation regarding their ability, and by such other evidence that they wish to submit. Only outstanding students in this category are admitted.

Admission to graduate courses may be granted only to those who have had the requisite undergraduate work in those courses. Students whose preparation is considered inadequate may be required to take without credit certain undergraduate courses.

Students from Foreign Countries. Students must be able to understand and be understood in English, both written and oral. This ability is tested in the applicant's own country with an English examination. Instructions concerning the test, if required, are sent to the applicant soon after his credentials have been received and evaluated. A placement examination in English is required at the time of registration on the campus. When indicated by the placement test, non-credit English courses are prescribed, which reduce accordingly the registration in credit courses and extend the time for completing degree requirements. Applicants who can present evidence that they satisfy the above requirements for language proficiency should submit a letter requesting admission, giving the following information in the order noted:

1. Your full legal name.
2. Address to which reply should be mailed.
3. Place and date of birth.
4. Name of the country of which you are now a citizen.
5. Subject in which you wish to specialize.
6. Your native language.
7. Whether you wish to be a candidate for an undergraduate or a graduate degree.
8. Amount in United States dollars available for your support, the source of your income, and the length of time this support is guaranteed.

[1] In converting to a numerical grade, the following equivalents are used: A = 5; B = 4; C = 3; D (minimum passing grade) = 2.

[2] All hours of credit are included for all courses in the semesters, quarters, or summer sessions involved in the last sixty semester hours, or 110 quarter hours, of undergraduate work and accordingly the total of hours used in the average may be greater than that noted. Courses failed and subsequently passed must also be included.

Before admission is granted each student is asked to present evidence that he has sufficient money to meet his expenses while attending the University of Illinois.

9. Complete chronological list of all secondary schools and colleges attended, giving the name and location of each with exact dates of attendance and diplomas, certificates, or degrees received. *Enclose official copies of your academic credentials.*

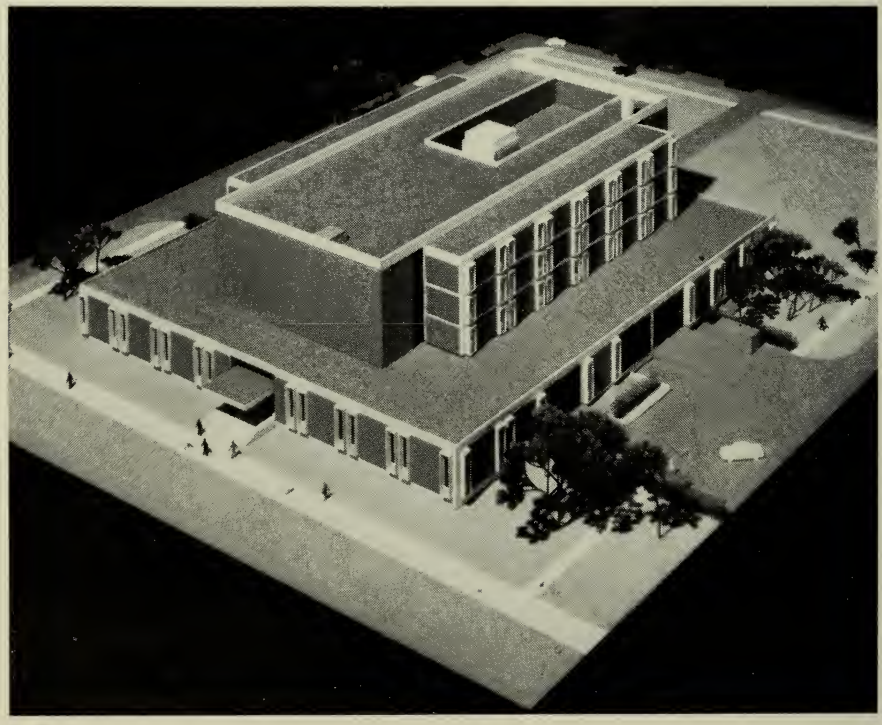
10. If you are not attending school, your occupation since leaving school.

11. Date you plan to enter the University of Illinois.

The Director of the Office of Foreign Student Affairs, 310 Student Services Building, University of Illinois, Champaign, Illinois 61822, U.S.A., assists students from abroad with problems involving passports, visas, and other matters.

Admission with Advanced Standing. Upon the recommendation of the head of the department and with the approval of the Dean of the Graduate

The new Civil Engineering Building is currently under construction, and the first phase as shown in this scale model will be occupied in November, 1965. Additional portions of the building are scheduled for completion in the following years. More than 200,000 net square feet of space will provide the most modern facilities for research and advanced study.



College, admission with advanced standing is granted to applicants who have completed a master's degree or the equivalent elsewhere and who desire to become candidates for the doctor's degree at the University of Illinois. A candidate for admission with advanced standing must meet the minimum standards noted above for entering graduates, and must exhibit an excellent record in his advanced work. The department desires, and may require, that a student supply in support of his application for advanced standing an official record of his Aptitude and Advanced Engineering scores in the Graduate Record Examination administered by the Educational Testing Service, Princeton, New Jersey. The record supplied must be for an examination taken during the preceding year.

The amount of credit to be accumulated at the University of Illinois before the candidate can be admitted to the preliminary examination can be determined only by the advisers in the major and minor fields after the student has registered and completed some work here.

Registration and Program of Studies

Registration. Actual dates for registration in the Graduate College are shown in the calendar, a copy of which will be sent upon request. Registration for the first semester is in the second or third week of September; for the second semester, the last week of January or the first week of February; and for the summer session, the middle of June. The registration of a new student is accepted at any time, provided he is prepared to enter courses already under way for credit reduced in proportion to the length of time which has elapsed since instruction began.

A graduate student obtains a program card, other registration material, and instructions from the department office during the scheduled registration days or at any time thereafter.

Advisers. Each graduate student is assigned an adviser who assists in planning and carrying through a program of graduate work which fits his needs and satisfies departmental and Graduate College requirements. The adviser for research assistants is normally the staff member in charge of each assistant's research program.

Unit Credit for Courses. Courses offering graduate credit are numbered from 300 to 399 when they are open both to advanced undergraduates and to graduate students, and are numbered 400 and above when they are open only to graduate students.

Graduate credit is measured in terms of units. One unit is considered the equivalent of four semester hours. The normal program for a full-time graduate student is four units each semester; the maximum permissible is

five units. The normal program for an eight-week summer term is two units, with two and one-half units being the maximum permitted.

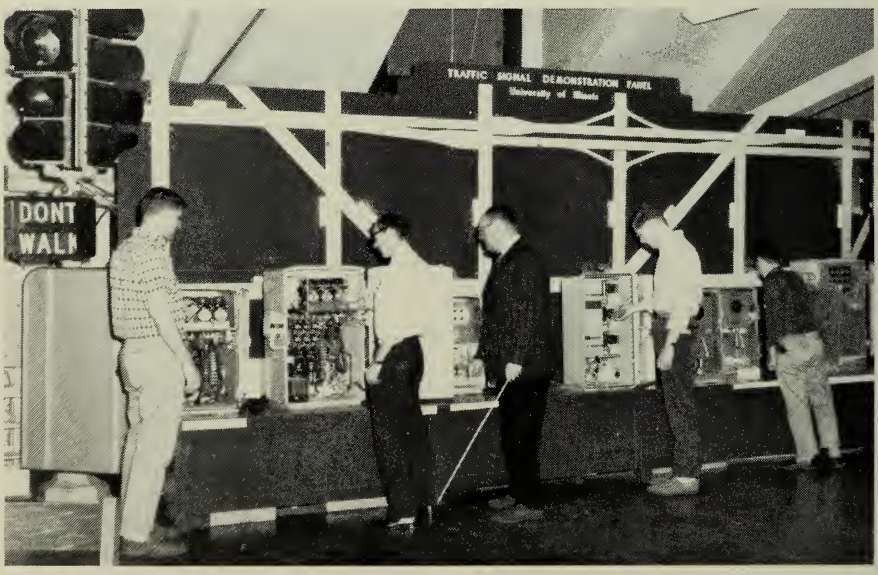
The amount of credit which may be earned in individual courses is indicated in the course listing and is in some instances variable. The credit for which the student is actually registered in every specific course is entered on the student's program card by his adviser and is subject to the approval of the Dean of the Graduate College.

Work Completed Elsewhere. A candidate for the doctorate, who has received a master's degree from a recognized institution, receives the equivalent of eight units of credit and one year's residence for that work. If such credit is to be used in partial fulfillment of the requirements for the doctorate, he is examined on the content of the courses involved at the time of the preliminary examination.

A graduate student who has done graduate work in a recognized institution, but without receiving a degree, may petition to obtain credit toward an advanced degree by passing examinations in this work. Admission to such examinations requires the approval of the department and of the Dean of the Graduate College. The acceptance of credit for work completed elsewhere does not reduce the residence requirement for the degree sought.

Upon recommendation of the department, the Graduate College may permit a student to register for work at a laboratory elsewhere that offers

Professor J. E. Baerwald demonstrates a unique Traffic Signal Demonstration Panel to graduate students. All common types of intersections are illustrated. The signal controllers, in front of the panel, are connected to the panel lights for advanced students to study traffic flow problems.



facilities not available in Urbana. Such work is accepted for graduate credit only if it is completed satisfactorily. The amount of credit to be recorded is recommended by the department after receipt of the transcript and examination of the student.

Miscellaneous Courses. A graduate student carrying a normal graduate program may elect, in addition, one miscellaneous course (a course which does not give credit toward an advanced degree). If a graduate student enrolls for more than one miscellaneous course, he may not register for a full graduate program. Courses intended to teach graduate students a reading knowledge of French, German, or Russian are regarded as miscellaneous courses. A student who elects a miscellaneous course is required to register in it and do the assigned work.

Auditing Privileges. A graduate student is permitted to attend classes (other than laboratory courses) as an auditor, provided a form bearing the approval of the instructor and the Dean of the Graduate College is filed with the Recorder.

Graduate Programs for Employed Students. A student who is employed can not expect to complete his academic work as promptly as one who devotes full time to his academic program.

The academic work carried by assistants and others on the University staff is limited by statute. Those employed outside the University are expected to reduce their programs of work in accordance with these regulations. The maximum amount of academic work is determined by the terms of employment as follows:

Nature of Appointment	*Maximum Registration*	
	Semester	*Summer Session*
Full time	1 unit	1 unit
Three-fourths time	2 units	1¼ units
Two-thirds time	2¼ units	1½ units
One-half time	3 units	1¾ units
One-third time	3¾ units	2 units
One-fourth time	4 units	2 units

Under exceptional circumstances, additional registration is permitted by the Dean of the Graduate College to allow for special conditions.

Time Limit for Advanced Degrees. A candidate for the master's degree must complete all requirements for the degree within five calendar years after his first registration in the Graduate College.

A candidate for the doctor's degree must complete all requirements for this degree within seven calendar years after his first registration in the Graduate College, except as noted below.

A candidate for the doctorate who has received a master's degree elsewhere must complete all requirements for the degree within five years

after his first registration in the Graduate College. This same regulation applies to the candidate who has received his master's degree from the University of Illinois and whose studies were interrupted immediately thereafter, provided not more than the minimum number of units required for the master's degree are applied to the doctorate.

In general, the transfer of graduate credit from other institutions under circumstances not specifically defined above is considered a basis for proportionate reduction of the time allowed for earning a degree.

Graduate Study in the Summer. During the summer session, a student may take courses for credit toward higher degrees, subject to the residence requirements listed below. The normal program for a summer session is two units; in no case is a student permitted to carry more than two and one-half units.

A limited number of civil engineering graduate courses are offered during the summer session. The fields included are usually structures and soil mechanics and foundations. The courses offered vary from summer to summer, so that by careful planning, it is possible to complete the requirements for the master's degree by summer study and make progress toward the doctor's degree. It is not possible to obtain a doctoral degree in civil engineering by attending only summer sessions.

Professor S. J. Fenves (left) and Professor L. R. Shaffer (right) discuss a computer program with Mr. E. L. Murphree, Jr., a Research Associate of the Civil Engineering Systems Laboratory.

Grades. Grades are recorded by letters as follows: for thesis research, S and U (satisfactory and unsatisfactory); for courses, A, B, C, D, and E (failure). A student with three units of grade below B is disqualified as a degree candidate. If he has received two but *less* than three units of grade below B, then all units he submits for the degree must be of A or B grade. Uncompleted work may be recorded by a deferred grade (Df); but such work, except that of thesis research, must be completed no later than the end of the next semester in which the student is registered.

Petitions. The normal procedures and requirements of the Graduate College are indicated in this pamphlet, but these may be modified occasionally for justifiable reasons. A student may petition to the Dean of the Graduate College for exceptions, but he should do so only after consultation with his adviser and with the recommendation of the department. Forms may be secured through the Department of Civil Engineering office.

Residence. Each degree candidate must spend a specified period of time in residence. The residence requirement is satisfied when a student lives in the community, or its immediate surroundings, and devotes an appreciable fraction of his time to graduate studies. A student who is regularly employed

A rainfall simulator developed under the direction of Professor V. T. Chow and being observed by a research assistant. It will be used to investigate basic watershed hydraulics, thus enabling students to participate in active research programs while working towards their advanced degrees. This program is being sponsored by the National Science Foundation.

outside the Champaign-Urbana community is not considered to be in residence even though he is registered in a campus course.

Multiple Degrees. No more than two graduate degrees will be conferred for work completed at the University of Illinois. This means that a student intending to obtain a doctorate should not enroll for a master's degree in more than one department.

The Degree of Master of Science

The degree of Master of Science is offered in the fields of civil engineering and sanitary engineering.

Credit Requirements. A candidate for the master's degree must complete at least eight units of graduate work with satisfactory grades. Three of the eight units must be in courses numbered in the 400 series, and two of these three must be in the major field. A total of at least four units must be in the major field. When a thesis is not elected or required, the candidate must present at least nine units of course work.

Residence Requirements. A candidate for the master's degree must spend at least two semesters in residence and must earn at least half of the required units while in residence. Attendance during four summer sessions in each of which the student is registered for not less than one unit of work, or in one semester with not less than two units and two summer sessions with not less than one unit each, is regarded as the equivalent of two semesters in residence. Registration for more than two units in a regular semester, or for more than one unit in a summer session, does not shorten the time which must be spent to discharge the residence requirement.

Majors and Minors. A candidate for a master's degree may do all his work in one field, or he may select a major and one minor, or a major and two minors. A major or minor denotes the field of knowledge of a department, or such part thereof as constitutes a separate and independent division of that field. For a master's degree a major comprises work totaling a minimum of four units. Less than one unit of work does not satisfy the requirements for a minor.

Foreign Language. During the first year of graduate study a student who plans to become a candidate for the Doctor of Philosophy degree should qualify in at least one of the languages required by the Graduate College.

Thesis. If a student elects to prepare a master's thesis or is required to do so by the department, he should file the subject of the thesis at the Graduate College office at least six weeks prior to graduation. No more than three units of thesis credit may be included in an eight-unit program. Credit in thesis research can not be applied to a degree unless a thesis is submitted.

When a thesis is not elected or required, the candidate must present at least nine units of course work.

For specific instructions with reference to the preparation and form of the thesis, the student should obtain at the Graduate College office a copy of the leaflet "Instructions for Preparation of Theses." Two copies of the thesis with Certificate of Approval must be presented to the Graduate College office by the date specified in the calendar of the Graduate College. In the Department of Civil Engineering, candidates are expected to prepare at least five copies of the thesis. The original and first carbon must be deposited in the Graduate College; two are for the major department and one for the author. The Certificate of Approval for the master's thesis must be signed by the person under whose immediate supervision the thesis was prepared and also by the head of the major department. Blank certificate forms can be obtained at the Graduate College office.

Thesis Work on Leave of Absence. A student who has completed six units of course work in residence and who wishes to complete the thesis in absentia should consult first with his adviser. If the request meets with the latter's approval, a petition is submitted. The petition must include an outline of the proposed investigation and evidence that adequate facilities for pursuing it are available. If the work is to be done in an industrial laboratory, it is necessary to secure a letter from the company releasing to the University all patent and publication rights.

Research assistant determining the organic carbon content of a soil to relate it to the engineering properties of a soil.

Suggested Programs. Suggested programs in the various fields in civil and sanitary engineering are presented on page 64.

Conferring of Degrees. The master's degree is conferred in February, June, August, and October. Each student is responsible for entering on his registration cards, during the registration period preceding the time at which he expects to be awarded his degree, the fact that he is a candidate for a degree to be awarded at the end of that semester. If the candidate is not currently registered in the Graduate College, he must present his application to receive a degree at the Graduate College office not later than the final date specified by that college.

Not later than one week before the degree is conferred, each candidate for an advanced degree must obtain a clearance paper from the Graduate College. The student must obtain all the signatures called for on the form, including departmental requirements, and return it to the Graduate College.

The Degree of Doctor of Philosophy

The degree of Doctor of Philosophy, primarily a research degree, is offered in the fields of civil engineering and sanitary engineering.

Residence Requirements. A doctoral program includes three stages of progress. At least two of these stages must be completed in residence, and the period in residence must include two successive semesters in the second or the third stage.

The first stage is completed when the candidate has received a master's degree or has earned the equivalent number of credit (eight units or thirty-two semester hours). The second stage consists of eight units of work, fulfillment of the major and minor course requirements, the language requirements (if not completed earlier), and a successful preliminary examination. The third stage is devoted to research and seminars (eight units), the preparation of the dissertation, and the final examination.

It is possible to complete these three stages in three years if the student devotes full time to his academic program. For information concerning the maximum time allowed, see page 15.

Majors and Minors. A candidate is required to declare a major field of study and one minor (requiring four units) or two minors (requiring two units each). If he elects two minors, only one of them may be a division of the major department or field; a full minor must be entirely outside the department offering the major. The requirements for a minor in any field should be checked with the department concerned.

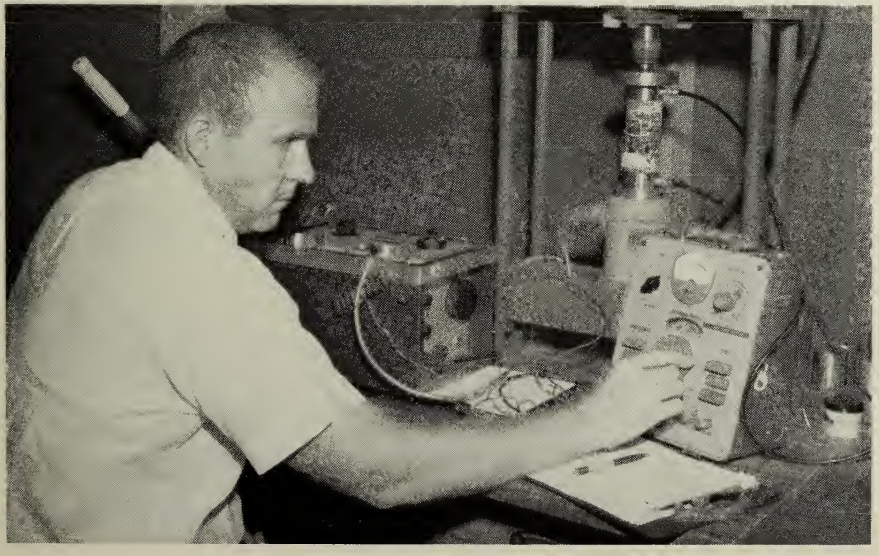
Language Requirements. A candidate is required to demonstrate ability to read two of the following languages: French, German, or Russian. A student who plans to become a candidate for the Doctor of Philosophy de-

gree should qualify in at least one of the required foreign languages during his first year of graduate study. A student must apply to take the examination in French, German, or Russian well in advance of the examination date. Deadlines for making application are given in the Graduate College calendar. The entire language requirement should be satisfied early in the doctoral program, in any event no later than two months before the preliminary examination, or during the semester (or summer session) preceding admission to the preliminary examination. Students majoring in civil engineering or sanitary engineering may satisfy the language requirements by (a) direct examination or (b) obtaining grades of A or B in French, German, or Russian 401. Certification of proficiency in foreign languages from other colleges or universities is not accepted by transfer.

Doctoral Committee. A permanent doctoral committee to conduct the preliminary and final examinations is appointed by the Dean of the Graduate College upon recommendation of the executive officer of the department in which the student is doing his major work.

Preliminary Examination. A candidate for the doctor's degree must pass a preliminary oral examination to test his knowledge of his major and minor fields of study. He is not admitted to the examination before (1) he has fulfilled the language requirement; (2) he has satisfactorily completed sixteen units of graduate work; and (3) the departments of his major and minor fields of study consider, through written examination or otherwise, that he has adequate preparation.

Research Associate R. P. Miller investigating the sonic velocity of rock under varying axial loads.



Final Examination. After the credit requirements for the third stage and the thesis have been completed, the candidate is admitted to the final examination upon recommendation of the major department. A student who has failed to maintain high standards of scholarship and research is refused admission to the final examination. Although the examination is concerned primarily with the research accomplished by the student as described in his thesis, it may extend over the candidate's whole field of study.

Latest dates for final examinations of candidates for degrees in February, June, and October are shown in the Graduate College calendar.

Thesis. The degree of Doctor of Philosophy is primarily a research degree and consequently the candidate must demonstrate his capacity for independent research by preparing an original thesis on a topic within his major field of study. The subject of the thesis must be reported to the doctoral committee and to the Graduate College at the time of the preliminary examination. After passing this examination, the candidate *must* register each term (summer sessions excluded) until he receives his degree. When the credit requirement is satisfied (eight units of thesis research subsequent to passing the preliminary examination) the student maintains his status as a candidate by registering for zero credit in Thesis Research (C.E. 499).

Directions regarding thesis form and style are given in the leaflet "Instructions for Preparation of Theses," copies of which may be obtained in the Graduate College office. The candidate must submit to the Graduate College, no later than the date specified in the current calendar, (1) the original and first carbon (or two copies reproduced by an approved method) of his thesis and (2) one typewritten copy of an abstract of not more than six hundred words. In addition, two copies must be presented to the major department and one copy should be retained by the author.

Each candidate who passes the final examination must pay a $25.00 microfilm fee. This provides for (1) microfilming of the complete thesis, with one copy deposited in the University of Illinois Library, and (2) publication of the abstract in *Dissertation Abstracts.*

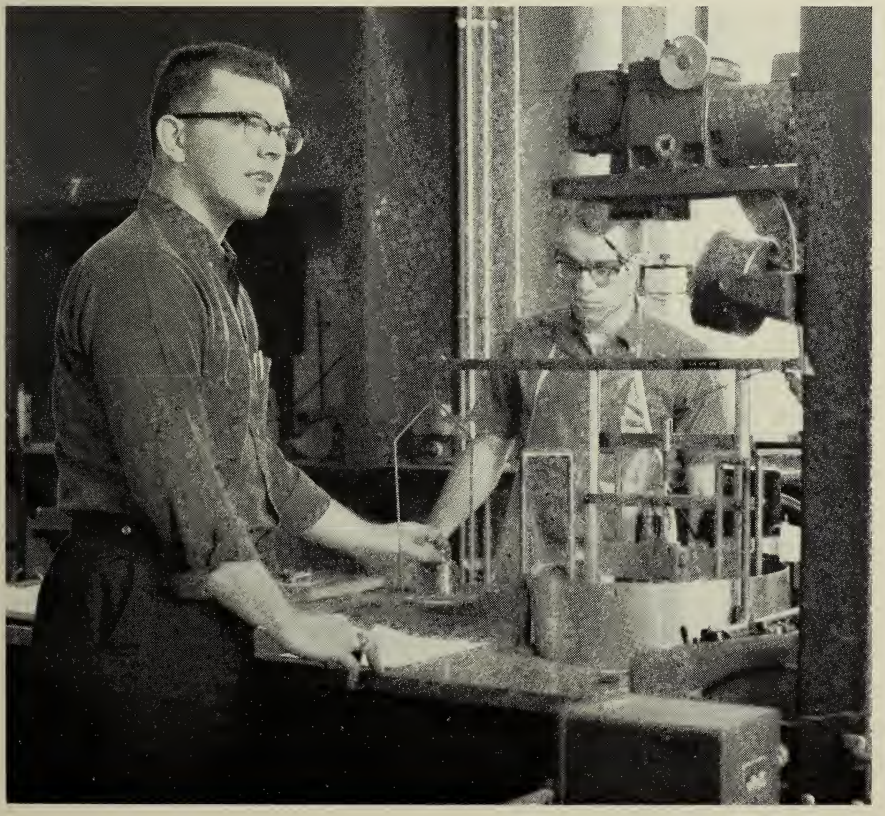
Conferring of Degrees. The doctor's degree is conferred in February, June, and October. Not later than one week before the degree is to be conferred, each candidate for an advanced degree must obtain a clearance paper from the Graduate College office. The candidate must obtain all the signatures called for on the form, including departmental requirements, and then return it to the Graduate College.

Financial Assistance

Various types of financial assistance are available each year to promising graduate students. Detailed information about the qualifications and appli-

cation procedures for these awards is given in the brochure "Financial Aid for Graduate Students." This brochure, application form, and instructions will be furnished upon request to the Graduate College or the department. Except for the National Science Foundation Cooperative Graduate Fellowship, only one University application form is needed to apply for any or all of the types of financial aid offered by the University. This one form may be used for fellowships (or traineeships), teaching fellowships, assistantships (teaching or research), and tuition and fee waivers. To be considered for a fellowship (except National Science Foundation Cooperative), research assistantship, or tuition and fee waiver for the following academic year beginning in September, the application and *all* supporting material must be returned to the Head, Department of Civil Engineering, by February 15. Although applications for tuition and fee waivers and assistantships are accepted after that date for any additional openings that possibly may become available, applicants for such appointments are strongly urged to sub-

Shear properties of asphalt in thin films are tested under conditions of different temperatures and stresses to determine shear rates.



mit their applications as early as possible since most awards are offered at the same time that applications for fellowships are considered.

Applicants for financial aid whose native language is not English should submit their application material by November 1 or earlier in order to allow time for the University to arrange for the English language examination as explained under Admission. All financial stipends granted by the University of Illinois (as well as admission) require certification as to the English proficiency of the student.

It is a requirement for many types of stipends that students take the Graduate Record Examination as a part of their qualifications for consideration for financial support. Students are advised that it is to their advantage to take the Graduate Record Examination, and specifically the Aptitude Test (Quantitative and Verbal), and the Advanced Engineering Examination, and have the results forwarded to the Department of Civil Engineering at the University of Illinois. Information as to when and where the Graduate Record Examination is given (generally administered world-wide) may be obtained by writing directly to the Educational Testing Service at Princeton University, Princeton, New Jersey.

Also required of prospective civil engineering graduate students seeking financial support is a statement of rank in class and rank in college. Mimeographed forms for this purpose are available and are sent with application material. One form is to be filled out and returned by the applicant; the other one is to be filled out and returned by the appropriate school official.

Principal Types of Fellowships

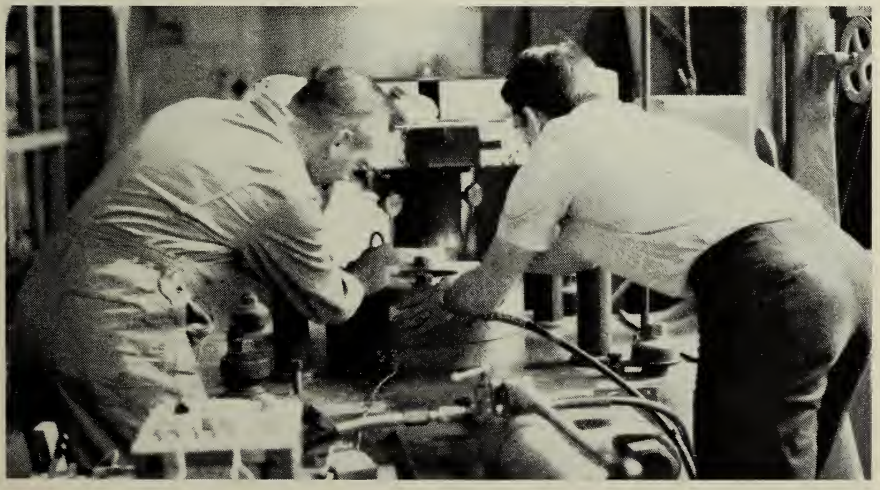
University Fellowships. University Fellowships, which are awarded on the basis of an all-University competition and are unrestricted as to the student's field of graduate study, provide tax-free stipends of not less than $1,800 for the nine-month academic year, or $2,250 for eleven months, with exemption from tuition and fees. During the past several years the stipend has been supplemented for approximately the upper quarter of the successful fellowship applicants. In addition, a student receiving a University Fellowship may accept, if offered, a part-time teaching assistantship not to exceed one-quarter time. University Fellows must carry a full program, four units or the equivalent. A number of summer fellowships that carry stipends of $450 with the usual exemption from tuition and fees are awarded to teaching assistants. These fellowships are restricted to graduate students who have held teaching assistantships at the University of Illinois for at least half-time for both semesters of the preceding academic year, who have earned not less than two units nor more than six units of graduate credit during that year. Like regular University Fellows, they are selected on the basis of an all-University competition.

Industrial Fellowships. These fellowships are provided by industrial firms, foundations, and private individuals and are available in several areas of graduate study in civil engineering. The recipients are selected from the applicants for general University of Illinois stipends.

National Defense Graduate Fellowships. The University of Illinois Graduate College has a number of National Defense Graduate Fellowships which are financed under Title IV of the National Defense Education Act of 1958 and administered with the cooperation of participating universities. Each fellowship, restricted to citizens or permanent residents of the United States, is for a three-year period to a student beginning his graduate studies. The current stipend for the academic year is $2,000 for the first year, $2,200 for the second, and $2,400 for the third, plus an additional allowance of $400 per year for each dependent. National Defense Graduate Fellowships carry the usual exemption from tuition and fees. Under certain conditions, National Defense Graduate Fellows may engage in a limited amount of teaching. These fellowships are granted to the University on the basis of specific proposals made each year; thus the number of available awards, and areas of study, vary from year to year.

National Aeronautics and Space Administration Traineeships. The National Aeronautics and Space Administration sponsors a number of traineeships at the University of Illinois for students who are majoring in the space-related sciences of technology. Awards are made to first-year graduate students and provide an annual tax-free stipend of $2,400 for twelve months, with exemption from tuition and all regular fees that are assessed at the time

Professor Harrison Kane, left, and an advanced undergraduate student, conduct a high pressure compression test on sand, an Air Force Weapons Laboratory project.



of registration. An allowance of up to $1,000 is provided for dependents. The traineeship may be renewed for a total of three years. NASA trainees must carry a full program, four units or the equivalent. Recipients are selected from the applicants for the general University of Illinois stipends. See procedure for application under Financial Assistance, page 22.

National Science Foundation Cooperative Graduate Fellowships. These fellowships are financed by the National Science Foundation, but are administered with the cooperation of the University. They are restricted to citizens of the United States who are graduate students in engineering sciences (or certain other sciences). Each fellowship carries a stipend of $2,400 for the first year, $2,600 for the intermediate year, and $2,800 for the terminal year, plus exemption from tuition and fees. An allowance of $500 is granted for each dependent. Nine-month awards amount to three-quarters of the above levels. First-year applicants may apply for tenures of one or two academic or calendar years; renewal is subject to satisfactory progress and availability of funds. Under certain conditions, National Science Foundation Cooperative Fellows also may engage in a limited amount of teaching.

National Science Foundation Graduate Traineeships. These traineeships are financed by the National Science Foundation but are administered by

Biological respiration rates of activated sludge are being measured by a research assistant and Ph.D. candidate. Professor R. E. Speece, right, observes the techniques used for this research project, sponsored by the U. S. Public Health Service.

the department, through the Graduate College. The basic twelve-month stipends are $2,400 for the first-year level, $2,600 for the intermediate year level, and $2,800 for the terminal year level. An allowance of $500 is granted for each dependent. Nine-month awards amount to three-quarters of the above levels. The recipients of these traineeships are selected from the applications for general University of Illinois stipends.

Public Health Service. Sanitary Engineering Traineeships and Radiological Health Fellowships. Sanitary Engineering Traineeships are for graduate students in the Water Supply and Pollution Control fields while the Radiological Health Fellowships are for those in the Radiological Health Specialist Program. Recipients receive $250 per month plus $30 a month for each dependent, tuition and fees, and a travel allowance to the University. Information regarding either of these U.S. Public Health Service grants should be requested from the Department of Civil Engineering, University of Illinois.

Tuition and Fee Waivers. These awards provide exemption from tuition and all fees except the hospital-medical-surgical insurance fee for the academic year and the following summer session. Students holding these awards must be in residence and must register for at least three units each semester during the academic year. They may, however, accept part-time or incidental employment not to exceed twenty hours a week either within or outside the University.

Selection of Fellows. Fellows are selected by the Graduate Fellowship Committee on the basis of scholarship and promise in teaching or research. All applicants are informed of the disposition of their applications on or about April 1. Successful applicants are expected to accept or decline by April 15. (See Acceptance Agreement, page 30.)

Departmental Requirement for Fellows. The department requires that all students holding fellowships be engaged in some form of active research, either in association with one of the department's formal research programs, or on a special research program with his adviser. All students holding a first-year fellowship must arrange to write a master's thesis, (C.E. 499M), or take at least one unit of Special Problems, (C.E. 497), involving a comprehensive report on an individual investigation. This phase of the program provides the student with valuable training and serves as a guide to the department in making decisions about continuing studies and stipends. Second- and third-year fellows necessarily will be involved in research (and should be enrolled for credit accordingly) as a part of their doctoral study.

Assistantships

Research Assistantships in the Engineering Experiment Station. The Engineering Experiment Station is devoted to the study of problems of

special importance to engineering and to the stimulation and elevation of engineering education. By undertaking a program of graduate study in close association with some one of the projects carried on in the Station, the student comes into contact with aspects of his specialty which he would rarely touch in a purely academic study, and thus broadens his outlook. The Experiment Station makes available apparatus, equipment, and the services of machinists, which materially facilitate the carrying on of investigations.

Half-time research assistantships, with a stipend of at least $2,400 for an academic year of two semesters, are open to graduates of approved technical colleges and universities. Applicants to whom these assistantships are awarded devote one-half of their time to the work of the Engineering Experiment Station and one-half to graduate studies. Each appointment is made for one academic year and normally is extended to permit the requirements for the master's degree to be satisfied. At the end of the extended period, if all requirements have been met, the degree of Master of Science is conferred. In general, with a half-time assistantship, two academic years of residence are required in order to obtain the master's degree. Half-time or full-time work at a comparable rate for two and one-half months is usually available during the summer months. Normally only half-time employment for two and one-half months is available in the summer for a new research assistant beginning in June. Thus, with an academic year half-time and a summer full-time appointment an assistant's annual stipend during the first year can be $3,733, plus exemption from tuition and fees during the academic year, but not the summer if employed full time. Generally a commitment for a summer appointment can not be made in advance of the spring term preceding the summer session. A limited number of appointments are available, with prior arrangement, that permit completion of work for the master's degree by attending two consecutive summer sessions and the two regular semesters between them, or alternatively in three regular semesters.

Appointments to research assistantships are made only to students with outstanding records. Appointments are given to first-year and second-year graduate students, but only rarely to third-year students who have not previously studied at Illinois. Study toward the degree of Doctor of Philosophy also may be pursued by research assistants who have already received a master's degree and who satisfy the requirements of the department and the Graduate College.

Students holding academic appointments requiring service for more than 67 per cent time are required to pay tuition and fees. Thus those assistants holding full-time appointments during the summer must pay fees. Those whose appointments call for a lesser percentage of time receive

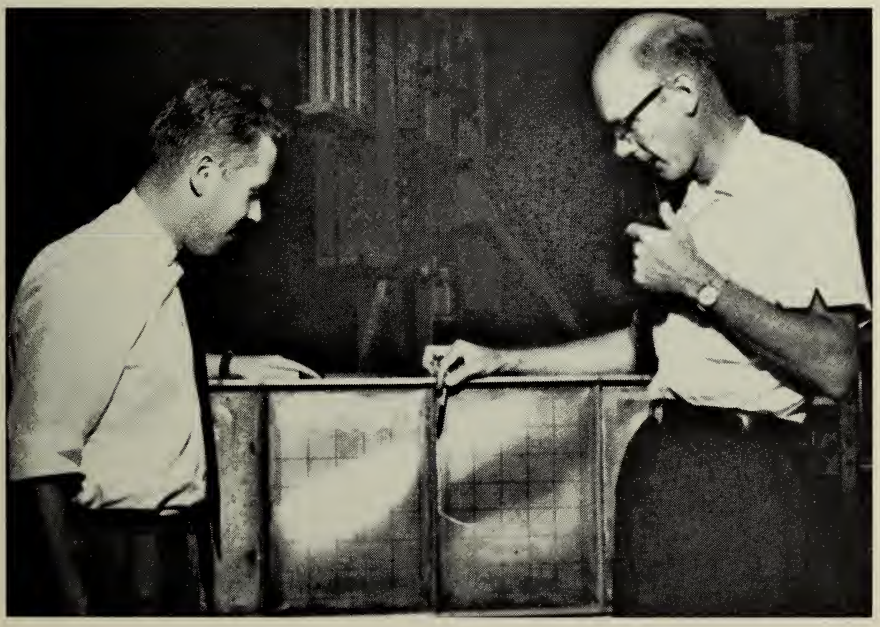
exemption from tuition and all fees except the hospital-medical-surgical insurance fee. Assistants must carry a reduced program of study, as shown on page 15.

A number of research assistantships in civil engineering and sanitary engineering are available. They include assistantships established by the University, and others provided by cooperative research agreements with state and federal agencies, technical societies, and engineering associations. Two half-time University research assistantships designated as the Terzaghi Assistantships are reserved for students primarily interested in soil mechanics.

Fields of research now active include all the programs shown in the introduction. Most programs have both experimental and analytical phases, and in general both aspects are combined in each project in order to permit broader training. It is usually possible to assign a research assistant to a project in the field of his special interest.

A thesis or research report is required at the master's level for all research assistants. Often the research in which he is engaged forms the basis of his thesis, but his thesis is not restricted to this field. Research assistants generally should register for special problems or thesis research during their first semester in order to gain additional experience in their area of research.

A research assistant, left, and Prof. J. E. Stallmeyer inspect a thin web girder which failed as a result of repeated load applications. This research is sponsored by the Bureau of Public Roads, Department of Commerce.



Applications for research assistantships should be made to the Head of the Department of Civil Engineering, preferably not later than February 15 to be considered for appointments effective the following September. Applications received after this date are considered for any vacancies that may still exist. Although most appointments are made for the academic year beginning in September, some appointments may also be available in February or June.

Teaching Assistantships. In general the department does not grant teaching assistantships to new graduate students. The normal procedure is to select teaching assistants from the research assistants who have served at least one semester in that capacity. Prospective graduate students who are interested in teaching should apply for a regular research assistantship and subsequently make their desires known to their adviser and to the head of the department.

Other Financial Aids

A number of other sources of support are available, as for example, Title IV Fellows under the National Defense Education Act and the American Society of Civil Engineers. Students are encouraged to apply for such stipends.

Acceptance Agreement

The University of Illinois adheres to the following resolution adopted by the members of the Association of American Universities and a number of other graduate schools of North America:

"In every case in which a graduate assistantship, scholarship, or fellowship for the next academic year is offered to an actual or a prospective graduate student, the student, if he indicates his acceptance before April 15, will still have complete freedom through April 15 to reconsider his acceptance and to accept another fellowship, scholarship, or graduate assistantship. He has committed himself, however, not to resign an appointment after this date unless he is formally released from it."

Loan Funds

University loan funds have been established for the benefit of worthy students who need financial assistance. The University of Illinois also participates in the Student Loan Program under the National Defense Education Act. Application forms and additional information on loans may be secured from the Dean of Students' Office, 346 Student Services Building.

Fees and Expenses

Tuition and other fees, as indicated below, are payable in full when the student registers, unless the installment plan of payment is elected.

SEMESTER TUITION AND FEES

	Full Program	*Partial Programs*	
	Range I	Range II	Range III
	Above 2½ units	Above 1¼ to 2½ units	Above 0 to 1¼ units
Tuition Fee			
Residents of Illinois	$ 85.00	$ 60.00	$ 35.00
Nonresidents of Illinois	260.00	180.00	105.00
Service Fee[1] — Resident and Nonresident	40.00	25.00	10.00
Hospital-Medical-Surgical Insurance Fee[2]	10.00	10.00	10.00

SUMMER SESSION TUITION AND FEES

	Full Program	*Partial Programs*	
	Range I	Range II	Range III
	Above 1¼ units	Above ¾ to 1¼ units	Above 0 to ¾ unit
Tuition Fee			
Residents of Illinois	$ 45.00	$ 30.00	$ 20.00
Nonresidents of Illinois	130.00	90.00	55.00
Service Fee[1]	20.00	13.00	5.00
Hospital-Medical-Surgical Insurance Fee[2]	5.00	5.00	5.00

SPECIAL FEES

Late Registration Fine $15.00

All students, whether on appointment or not, who register for courses on campus after the close of the regular registration are subject to this fine in addition to the tuition and fees. Students who register late in any term pay the same tuition and fees as students who register at the beginning of the term.

Change of Program Fee 1.00

This fee is charged for every change slip issued at the request of the student after the completion of registration.

"In Absentia" Registration

Graduate students enrolled for credit in thesis research for the master's or doctor's degree on leave of absence pay the same Tuition fee, resident or

[1] Persons on the academic, administrative, or permanent nonacademic staff of the University, or on the staffs of allied agencies, and persons registered in absentia or in courses taught off campus, are exempt from this fee. Persons registered on campus for thesis research only without credit are charged a $10.00 Service fee, in addition to a $10.00 Tuition fee and the Hospital-Medical-Surgical Insurance fee for regular semesters. Summer session Service and Hospital fees are $5.00 each. Persons not holding tuition waivers who are registered for less than a full program of credit courses (Range II or III) pay $15.00 for each noncredit course in addition to the required tuition and fees for the credit courses. If taken alone, noncredit courses other than thesis research and seminar are assigned to Range III.

[2] Students presenting evidence of equivalent coverage may receive a waiver of this fee upon approval of a petition submitted to the University Insurance Office not later than the final day established for full refund of fees. A signed waiver assumption of responsibility also is required. Persons registered for thesis research in absentia are not assessed this fee.

nonresident, as previously listed. They are exempt from the Service fee and the Hospital-Medical-Surgical Insurance fee.

Noncredit Courses

Graduate students registered on campus for thesis research only without credit are charged the following:

Tuition Fee $10.00
Service Fee 10.00
Hospital-Medical-Surgical Insurance Fee 10.00

Graduate students registered in absentia for thesis research without credit are charged a Tuition fee of 10.00

Persons registered in noncredit seminars, either alone or in addition to other courses ..... No charge

Persons not holding tuition waivers who are registered for less than a full program of credit courses (Range II or III) pay for each noncredit course 15.00

(This is in addition to the required tuition and fees for the credit courses.)

Off-Campus Courses (field courses)

Students pay the regular Tuition and Hospital-Medical-Surgical Insurance fees. They are exempt from the Service and Activities fees.

Recreational Facilities Fee

Visitors pay each semester 12.00
For the summer session, $6.00.

Wives or husbands of students and members of the faculty pay each semester 6.00
For the summer session, $3.00.
For families, including children, each session, $8.00.

Visitor's Fee 15.00

Persons not otherwise registered in University courses and students registered on campus on a partial program fee schedule (Range II or III), except those holding scholarships, tuition waivers, or staff appointments, which exempt them from tuition for campus work unless such scholarships are specifically limited are charged this fee for each course attended as a visitor only. Visitors in extramural courses pay the regular fee assessed for the course. In the case of multiple credit courses, the visitor pays the lowest fee assessable.

Transcript Fee 1.00

Each student who has paid all his University fees is entitled to receive, without charge, one transcript of his record. For each additional transcript this fee is charged.

Installment Fee 2.00

Students electing the installment plan for payment of tuition and fees must pay this service charge. An additional service charge of $2.00 is assessed if the flight instruction fee is paid on the installment plan.

Delinquent installment charge (tuition, fees, and residence hall charges)

is 2 per cent monthly, but not less than $1.00. (Additional penalties, including cancellation of registration, may be imposed.)

Unredeemed Check Service Charge 2.00

This charge is made for each check returned by banks to the Business Office for insufficient funds or other reasons. (Additional penalties, including cancellation of registration, may be imposed.)

Motor Vehicle Registration, each semester 7.50

REFUND OF FEES

A student subject to tuition and/or fees who withdraws from the University during any term may receive refunds. See the Graduate College catalog for details.

Housing

The University has residence facilities for single graduate students, both men and women, and a limited number of apartments in University-owned student-staff apartment buildings. Applications for both rooms and apartments may be obtained from the Housing Division, 420 Student Services Building, University of Illinois, Champaign, Illinois 61822. In addition, the Director of Housing maintains a list of apartments and rooms available in private homes in the community.

Buildings and Equipment

The teaching and research activities of the Department of Civil Engineering are conducted in portions of two major buildings — Civil Engineering Hall and Talbot Laboratory — and several smaller buildings, including the Sanitary Engineering Laboratory, the Wood Shop Building, the Hydraulic Engineering Laboratory, the Test Track Building, and two Structural Annexes.

New Civil Engineering Building. Currently under construction is Phase I of the new Civil Engineering Building, which will be among the best research and training facilities in the country. When completed and equipped, the new facility will have over 200,000 net square feet of space, and its estimated cost will exceed 10 million dollars. The first phase is to be completed in late 1965 or early 1966, and will provide areas for concrete structures, steel structures, soil mechanics, sanitary engineering laboratories, and research and graduate study. As the building is completed the Department of Civil Engineering will be brought together from twelve different locations on the campus.

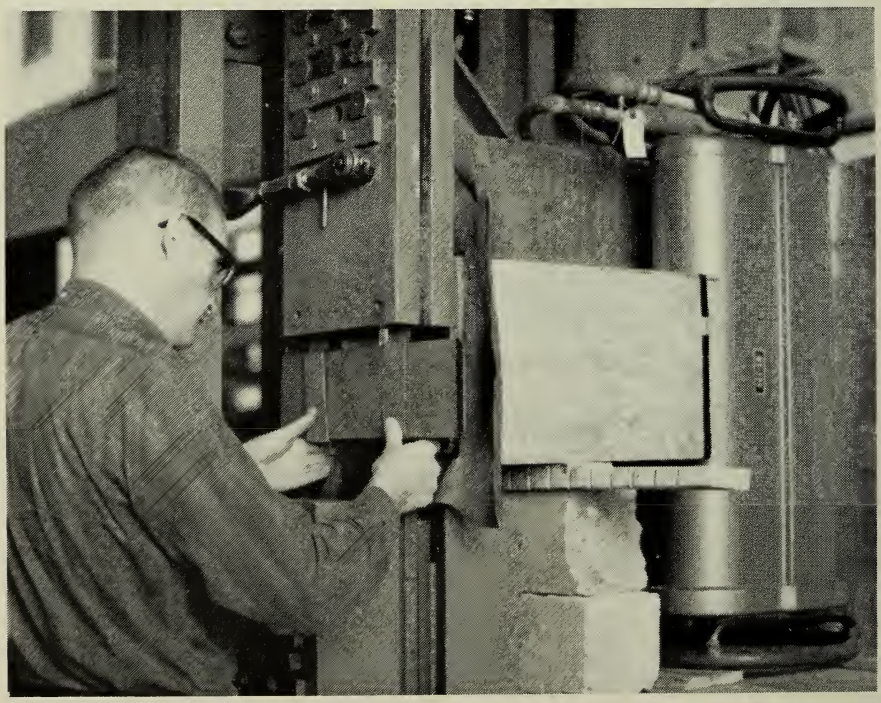
Concurrent with the completion of the building, the most modern research, testing, and training equipment will be accumulated to provide for the highest quality of civil engineering research and training.

Civil Engineering Hall. This building, with a floor area of 64,000 square feet, houses the department office, offices of members of the staff, classrooms, a graduate study room, a student lounge, the Engineering Library, the College of Engineering administrative offices, and some offices of the Institute of Aviation.

Located in Civil Engineering Hall are the facilities for the Construction Engineering and Management Programs. Scientific methods for conceptualizing, analyzing, planning, and controlling of construction operations are being developed. The group makes extensive use of the IBM 1620 data processing system in the Civil Engineering Systems Laboratory.

The traffic engineering laboratory for teaching and research is located in this building. The laboratory contains a traffic signal demonstration panel which can be operated individually or collectively with all types of signal controllers, radar speedmeters, traffic counters, a twenty-pen recorder, a traffic operations model, volume or density computer, and other technical equipment. The traffic laboratory is supplemented by the use of the Highway Traffic Safety Center's research vehicle which can measure driver, vehicle, roadway and traffic flow characteristics.

A research assistant prepares to X-Ray a weld in HY-80 steel. This research is sponsored by the Department of the Navy, Bureau of Ships, on steel that is used in naval construction.



Talbot Laboratory. The Talbot Laboratory is the outstanding building of its kind in the country. Its floor area of 82,000 square feet is shared by the Department of Civil Engineering and the Department of Theoretical and Applied Mechanics. It houses the following laboratories for testing, research, and instruction.

The *structural laboratory* is in the large central crane bay, where testing machines varying in capacity from 30,000 pounds to 3,000,000 pounds are located. The latter machine has a vertical height sufficient to accommodate tension and compression specimens thirty-eight feet long. Large machines for determining the fatigue strength of full-size structural members and the strength of members subjected to rapidly applied loads and extensive hydraulic loading facilities are important features of this laboratory. The laboratory contains electronic data reduction equipment, a metallurgical laboratory, a machine shop, and a welding shop, all of which are used in the department's instruction and research program. These extensive facilities are available to study the fundamental behavior of structures and structural components of wood, steel, and other metals, reinforced concrete, and prestressed concrete, and for the study of dynamic behavior of structures as influenced by various forms of excitation including vibration, impact, earthquakes, and blast.

The *concrete laboratory* is equipped for the study of the physical properties of concrete as influenced by proportioning, mixing, placing, curing, and environment. The *highway materials laboratories* are equipped for tests and research in bituminous materials and mixes, as well as in stabilized soils, soil-aggregate mixtures, and other nonbituminous highway materials. The *soil mechanics laboratories* are among the most complete in the world. They contain equipment for the performance of consolidation tests, triaxial tests under dynamic and static loading through a wide range of pressures, and model tests for investigating a variety of soil-structure interaction problems. Special equipment is available for chemical and rheological studies of soils. The laboratories also are equipped for static and dynamic tests in rock mechanics. For aerial photo studies a *library* of photographs, geologic maps, and soils maps has been established. Various types of stereoscopes and a vertical reflecting projector are used in marking photos and preparing engineering maps.

Graduate students in civil engineering often elect courses which make use of the laboratories of the Department of Theoretical and Applied Mechanics which are also located in this building. The laboratories include the *hydraulics laboratory,* which is equipped with a standpipe, pumps, weirs, orifice tanks, turbines, long concrete channels, and other facilities for instruction and research in hydraulics; the *applied mechanics laboratory,* equipped with standard and special testing machines of various types and capacities;

the *fatigue of metals laboratory,* equipped with a variety of machines for testing metals under fatigue loading; the *concrete research laboratory,* which is well equipped with testing machines, mixers, a concrete saw, a core drill, and other tools and equipment used in fabricating and testing members of plain and reinforced concrete and which is supplemented by the large crane bay and its testing machines; and several special laboratories, such as those for plastics, photoelastic investigations, and creep of metals.

Sanitary Engineering Laboratory. A separate three-story brick building provides classrooms, offices, and laboratories for instruction and research in sanitary engineering. A wide variety of precision instruments is available for the physical, biological, radiological, and chemical, including biochemical, investigation of water, waste water, and air. The laboratory has pilot plants for the treatment of water and wastes with space and shop facilities available for the construction of additional apparatus and special equipment.

Research in the purification of air and water, in the treatment of domestic and industrial waste waters, and in other aspects of sanitary engineering requiring hydraulic, chemical, and biological equipment is being carried on in the Sanitary Engineering Laboratory. Opportunities

A graduate student operates a WILD PUG-3 Point Transfer Device in the Photogrammetry Laboratory.

to participate in the established projects and to pursue research independently on selected projects are offered.

Surveying and Photogrammetry Laboratories. These laboratories are now situated in a building north of Civil Engineering Hall and include an extensive collection of modern instruments which are used for advanced instruction and research in geodetic and photogrammetric engineering. For instruction in precise control surveying including geodetic astronomy, the following equipment is available: first-order Wild N-3 level, Wild T-2 theodolite with prismatic astrolable attachment, Zeiss pendulum level, lovar tapes, precise foot and yard rods, chronometer, etc. For advanced instruction and research in photogrammetry the following are available: Wild STK-1 Stereocomparator, Wild PUG-3 Point Transfer Device, Nistri, Photocartograph V, Zeiss SEG IV and SEG II rectifiers, Zeiss stereotope, stereocomparagraphs, sketchmasters, slotted templet cutter, stereoscopes, reflecting projector, etc.

Hydraulic Engineering Laboratory. The Hydraulic Engineering Laboratory occupies a total usable space in excess of 15,000 square feet. Over 70 per cent of the area is used for basic research in hydraulics and hydrology. The remainder of the area is devoted to offices, shop facilities, and darkroom. The main laboratory pumping system is composed of five pumps with a combined capacity of 5,000 gallons per minute at a head of about forty-five feet. Water storage and sump facilities, with a capacity in excess of 22,000 gallons, supply the water recirculation system. Piping arrangements are designed to permit simultaneous constant head and high rate flows without interference.

A separate system for the use of graduate students is maintained in the north laboratory. This test area contains its own pump, water supply, circulation system, and measuring apparatus.

Instrumentation is of the latest types. A unique feature of the laboratory is a heated space 10 feet wide and 330 feet long equipped with a traveling crane for the handling of heavy equipment. This space is well adapted to studies relating to either open channel or pipe flow.

Available within the laboratory are complete shop facilities for the construction of research installations and models, including apparatus for molding plastic materials.

Pavement Materials and Behavior Laboratory. Extensive facilities are available for evaluating paving materials and for studying the behavior of pavements under static and repeated dynamic loads. The pavement study area is located near the northeast corner of the campus and consists of three single-story buildings of about 6,200 square feet, plus outside area for storage and handling of materials.

The materials research laboratory contains facilities for conducting the

standard tests on paving materials, plus many pieces of special equipment designed at the University of Illinois. Facilities are available for handling and processing the large quantities of materials needed in the test pavements, including a mixer for blending concrete and stabilized paving materials, a small but complete hot-mix plant, compaction tools, and special equipment for pulverizing the soil and adjusting the water content.

The pavement behavior test area contains a test track in which either static or repeated dynamic loads can be applied to model pavements. Static loads up to 80,000 pounds can be applied to the test pavements as well as repeated wheel loads in excess of 3,000 pounds. The wheel loads can be applied at a rate of more than a quarter-million load applications per week. The pavement test area contains equipment for adjusting the water table below the test pavements and for control of the temperature and humidity of the atmosphere immediately above the test pavements.

Library Facilities. The University Library's resources for advanced study and research are outstanding. Its present collections now exceed 3,634,000 volumes, all but about 264,000 of them located in Urbana.

In addition to the figures for cataloged volumes cited above, the University Library contains approximately 514,000 pamphlets, 283,000 maps

Graduate assistants measure the flexural strength and rigidity of a soil cement used in a test road in Virginia. This research is a part of the National Cooperative Highway Research Program.

and aerial photographs, and 230,000 music scores and parts. More than 18,000 periodicals and newspapers are currently received.

The Library's bibliographical facilities comprise a general catalog of more than 4,000,000 cards, a union catalog of titles owned by about two dozen major American and foreign libraries; printed catalogs of libraries, e.g. the Bibliothèque Nationale, British Museum, and Library of Congress; national and trade bibliographies of all countries for which such works have been issued; bibliographies of special subjects; and similar aids.

Outstanding collections have been developed in the science-technology fields. The Engineering, Physics, Mathematics, Chemistry, and Geology libraries are located conveniently to the College of Engineering. Their combined collections include over 3,250 journal titles and 175,000 books. Graduate students have free access to all library bookstacks. Microreproduction and photo duplication facilities, interlibrary loan service from other institutions for those engaged in research for dissertations, individual reference service, and assistance in using the collections, catalogs, and indexes are also available.

Computational Aids. Available for civil engineering research are a number of computational aids for use in studies of numerical methods of various kinds, for the numerical solution of problems of stress analysis, instability, vibration, impact, heat flow, etc., and for data reduction and processing. For advanced study and research, the department has an IBM 1620 computer system located within Civil Engineering Hall in support of the Construction Engineering and Management programs, and other disciplines. In addition, computing facilities of the Digital Computer Laboratory are available for student use; this laboratory includes the Illiac II and an IBM 1401-7090 system. The Illiac, designed and built at the University, has a high-speed memory of 1,024 words and a magnetic drum memory of 12,800 words. The IBM 1401-7090 system includes a high speed disk file capable of storing several million words of information. Extensive program libraries are available for both the Illiac and the IBM systems. In addition to general programs, many special purpose programs developed by civil engineering staff and graduate students are available for the static and dynamic analysis and design of a variety of complex structures, for data reduction, for traffic and equipment allocation studies, for train performance simulation, for planning construction operations, and for many other research problems. Desk calculators are located in computing laboratories in Talbot Laboratory, Civil Engineering Hall, and the Structural Engineering Annexes. Use may be made of the IBM punched card tabulating and computing equipment in the Statistical Service Unit.

All the computing facilities are used extensively in the analytical and in the design-oriented research programs in civil engineering. They make

possible investigations involving complex computations which are impracticable or even impossible by other means and greatly expand the scope of both the analytical and design-oriented, as well as some phases of experimental research.

Courses in Civil Engineering and Sanitary Engineering

The prerequisite for graduate work in civil engineering and sanitary engineering is the equivalent of the undergraduate courses required for the degree of Bachelor of Science in the branch of the subject in which registration is desired.

Use of the designation I or II in the title of a course, indicates a course is given in two parts.

Courses for Advanced Undergraduates and Graduates

301. Advanced Surveying. Precise horizontal and vertical control surveys; state plane coordinate systems; special construction surveys. ½ unit. Prerequisite: Civil Engineering 202 or consent of instructor.

302. Photogrammetric Engineering. A study of metrical photography in civil engineering practice; characteristics and interpretation of aerial and terrestrial photographs; stereoscopic compilation of maps from photographs; mosaics; economics of photogrammetry; map reproduction. ½ unit. Prerequisite: Civil Engineering 202 or consent of instructor.

303. Property Location Surveys. Original, retracement, and subdivisional surveys in relation to real property. ½ or 1 unit. Prerequisite: Civil Engineering 201 or consent of instructor.

305. Observational Astronomy. Same as Astronomy 314. Astronomical coordinate systems and transformations; theory of, and practice in, approximate and precise determinations of latitude, longitude, and time; introduction to theory of errors; theory and practice of astronomical photography. 1 unit. Prerequisite: Astronomy 102 or 210, or Civil Engineering 201, Mathematics 142 or 143.

314. Fundamentals of Systems Approach. Introduction to the application of linear programming, network theory, and queueing theory to the synthesis of civil engineering systems. ½ or 1 unit. Prerequisite: Civil Engineering 215, Mathematics 263, or consent of instructor.

315. Construction Productivity. Introduction to the application of scientific principles to the measurement of and the forecasting of productivity in construction engineering; conceptual and mathematical formulations of the labor, equipment, and material factors affecting productivity. ½ unit. Prerequisite: Civil Engineering 215; credit or registration in Mathematics 263 or equivalent; or consent of instructor.

316. Construction Planning. Introduction to the application of scientific principles to the normative planning of construction operations. ½ unit. Prerequisite: Civil Engineering 315 or consent of instructor.

318. Construction Cost Analyses and Estimates. Introduction to the application

of scientific principles to costs and estimates of costs in construction engineering; concepts of and statistical measurements of the factors involved in direct costs, general overhead costs, cost mark-ups and profits; the fundamentals of cost recording for construction cost accounts and cost controls. ½ unit. Prerequisite: Civil Engineering 315 or consent of instructor.

321. Bituminous Materials and Mix Design. Properties and control testing of bituminous materials; analysis of bituminous paving mixtures; composition and design of asphaltic concrete and soil-asphalt mixes. ½ unit. Prerequisite: Civil Engineering 214 and 220, or consent of instructor.

322. Development of Highway Facilities. Analysis of factors in developing a highway transportation facility; traffic estimates and assignment; problems of highway geometrics and design standards; planning and location principles; intersection design factors; street systems and terminal facilities; programming improvements; drainage design; structural design of surface; concepts of highway management and finance; highway maintenance planning. 1 unit. Prerequisite: Civil Engineering 220 or consent of instructor.

325. Highway Traffic Characteristics. Vehicle operating characteristics; driver characteristics; pedestrian characteristics; roadway characteristics as they individually, and collectively as traffic stream characteristics, are related to the planning, design, and operation of highway facilities. ½ unit. Prerequisite: Civil Engineering 220 or consent of instructor.

333. Urban and Regional Transportation. Importance of transportation and its relation to urban and regional planning; characteristics of transport systems; transportation planning including surveys, data analysis, and problems of administration and finance; coordination and integration of transport. ½ or 1 unit. Prerequisite: Consent of instructor.

334. Airport Design. Basic principles of site selection for airports and fundamental considerations of design, construction, and maintenance of airport pavements and structures. ½ or 1 unit. Prerequisite: Civil Engineering 220 and senior standing in civil engineering, or consent of instructor.

335. Railway Construction and Maintenance. Loads and load distribution on track and subgrade; roadbed construction and stabilization; track stresses, design, and materials; turnouts and crossings; maintenance programs. ½ or 1 unit. Prerequisite: Consent of instructor; credit or registration in Civil Engineering 230 for those with a minor in railroad or transportation engineering.

336. Railway Location and Operation. Influence of traffic, alignment, distance, gradiants, and motive power upon operating expenses; mechanics of train operation; economic design of location. ½ or 1 unit. Prerequisite: Consent of instructor; credit or registration in Civil Engineering 230 for those with a minor in railroad or transportation engineering.

337. Signals. Train movements; systems of signals; track circuits; track capacity; interlockings; economics of signaling. ½ or 1 unit. Prerequisite: Consent of instructor; credit or registration in Civil Engineering 230 for those with a minor in railroad or transportation engineering.

338. Terminals. Design and operation of freight terminal facilities for rail, highway, air, and water carriers; passenger terminals; special terminal requirements for specific commodity categories; coordination. ½ or 1 unit. Prerequisite: Consent of instructor; credit or registration in Civil Engineering 230 for those with a minor in railroad or transportation engineering.

345. **Public Health Engineering.** The application of engineering principles to the control of environmental sanitation, including administration, biostatics, communicable disease control, epidemiology, industrial health and air contamination, housing, vector control, radiological health, refuse collection and disposal, milk and food sanitation, swimming pools, and individual water supply and waste water disposal. ½ unit. Prerequisite: Consent of instructor.

348. **Air Pollution.** A study of the characteristics of air contaminants from industrial and domestic sources; their effect and methods of control; air pollution surveys; organization of control programs. ½ unit. Prerequisite: General Engineering 360 or consent of instructor.

349. **Fundamentals of Radiation Protection.** Same as Nuclear Engineering 349. Principles and practice of health physics and radiation protection engineering, including such topics as: principles of dosimetry; sources of ionizing radiation; determination of radiation tolerances; dosimetric instruments; standards and regulations. ¾ or 1 unit. Prerequisite: Nuclear Engineering 397 or Physics 382, or equivalent.

351. **Hydromechanics.** Applied fluid mechanics with particular reference to topics in hydraulic design, analysis, and research in civil engineering areas; covers dimensional analysis and dynamic similarity, analysis of potential flow, boundary-layer problems, turbulence and diffusion, hydraulic transients, water waves, transport phenomena. ¾ unit. Prerequisite: Theoretical and Applied Mechanics 235; Civil Engineering 251.

352. **Water Resources Design.** Study and evaluation of various phases of river mechanics; water resources history and project implementation; development of a water resources project plan. ¾ unit. Prerequisite: Civil Engineering 250; Theoretical and Applied Mechanics 235.

353. **Hydraulic Structures.** Introduction to the design of hydraulic structures, including consideration of types and functions of dams; hydrologic design; hydraulic design of spillways and outlet works; determination of loads and stresses for concrete structures; seepage, piping, and stability of earth structures. ¾ unit. Prerequisite: Civil Engineering 250 and 251.

354. **Hydraulic Engineering Laboratory.** Fundamental principles, operation, and use of model laboratories; dimensional analysis; hydraulic similitude; theory and design of hydraulic models as applied to a specific laboratory problem. ¾ unit. Prerequisite: Theoretical and Applied Mechanics 235.

361. **Advanced Structural Analysis.** Numerical methods of structural analysis; general theory of continuity; prismatic and nonprismatic members; continuous framed structures; trussed structures; lateral load distribution; secondary stresses. ¾ or 1 unit. Prerequisite: Civil Engineering 262 or equivalent.

363. **Behavior and Design of Metal Structures, II.** Members under combined loads; welded, riveted, and bolted connections; moment-resistance connections; plastic design. ¾ or 1 unit. Prerequisite: Civil Engineering 263 or consent of instructor.

364. **Reinforced Concrete Design, II.** Limit design of continuous reinforced concrete members and slabs of various types. ¾ or 1 unit. Prerequisite: Civil Engineering 264; credit or registration in Civil Engineering 262.

366. **Behavior of Reinforced Concrete Members.** Ultimate strength and behavior of reinforced concrete members and relation between results of research and current specifications for design; members subjected to flexure, axial com-

pression, combined flexure and axial load, combined flexure and shear, and bond. 1 unit. Prerequisite: Bachelor of Science in civil engineering or architecture with courses in structures and reinforced concrete design.

368. Prestressed Concrete. Principles and methods of linear prestressing; behavior, strength, and design of noncomposite simple beams, composite simple beams, and continuous beams; time-dependent variables and long-time deflections. ¾ or 1 unit. Prerequisite: Civil Engineering 262 and 264.

369. Behavior and Design of Wood Structures. Theory and practice in design of modern wood structures; effect of plant origin and physical structure of wood on its mechanical strength; fasteners and their significance in design and the development of design formulae. ¾ or 1 unit. Prerequisite: Civil Engineering 261 or equivalent, or consent of instructor.

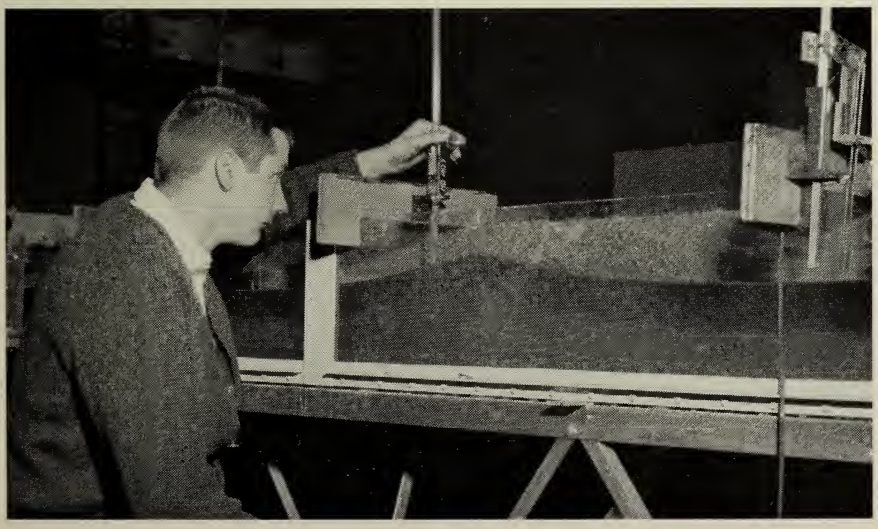
380. Foundation Engineering. Evaluation of subsoil conditions as they affect the behavior, proportions, and choice of type of foundations; bearing capacity and settlement analyses; character of natural soil deposits; earth pressure theories and retaining wall analysis; slope stability. 1 unit. Prerequisite: Civil Engineering 210.

383. Soil Mechanics. Identification, description, and classification of soils; index properties, weight-volume relationships; hydraulic properties; stress-deformation characteristics; ultimate strength; subsurface exploration; character of natural soil deposits. ¾ or 1 unit. Prerequisite: Consent of instructor.

384. Applied Soil Mechanics. Application of soil mechanics to foundations of buildings; stability of earth slopes; earth pressure and retaining walls; braced cuts; damage due to construction operations. ¾ or 1 unit. Prerequisite: Civil Engineering 383 or consent of instructor.

385. Engineering Aspects of Surficial Soils. Use of geologic and pedologic information and airphoto interpretation techniques in the prediction of engineering properties of soils and the planning of engineering soil surveys. Field

Using a locally fabricated model, a research assistant makes preliminary wave studies.



trip, estimated expense, $5.00. 1 unit. Prerequisite: Civil Engineering 210 or consent of instructor.

391. **Numerical and Computer Applications in Civil Engineering.** Introduction to digital computers and their programming; development of methods for the efficient use of computers in the solution of design and other problems; description of applications; discussion of role of computers in performing engineering computations. ½ or 1 unit. Additional work required for more than ½ unit of graduate credit. Prerequisite: Graduate standing in civil or architectural engineering, or consent of instructor.

Courses for Graduates

401. **Geodetic Engineering.** Elements of geodesy; principles and practice of precise triangulation, traverse, and levels. 1 unit. Prerequisite: Bachelor of Science in civil engineering. SCHMIDT.

402. **Geodic Engineering.** Precise astronomic determination of time, latitude, longitude, and azimuth. 1 unit. Prerequisite: Bachelor of Science in civil engineering. SCHMIDT.

403. **Photogrammetry.** Study of the principles of stereoscopy and geometrical optics; aerial cameras, their design and calibration; the design, construction, and operation of stereoscopic plotting machines; mathematics of stereoscopic orientation and model deformations. 1 unit. Presequisite: Civil Engineering 302, or consent of instructor. KARARA.

404. **Photogrammetry.** Theory of errors of stereoscopic photogrammetry; aerotriangulation (spatial and radial), its theory and applications to various civil engineering problems; electronics in photogrammetry; practice in compiling maps from aerial and terrestrial photographs. 1 unit. Prerequisite: Civil Engineering 302, or consent of instructor. KARARA.

416. **Design of Construction and Industrial Operations, I.** Same as Industrial Engineering 416. Conceptual development of a systems design procedure for optimal design of construction and industrial operations; general forms required for critical path networks, linear programs, theory of queues and inventory models required for systems design; design evaluation and control models. 1 unit. Prerequisite: Bachelor of Science in civil or industrial engineering; credit or registration in Mathematics 363; or consent of instructor. SHAFFER.

417. **Design of Construction and Industrial Operations, II.** Same as Industrial Engineering 417. Continuation of Civil Engineering 416. 1 unit. Prerequisite: Civil Engineering or Industrial Engineering 416; credit or registration in Mathematics 315; or consent of instructor. SHAFFER.

420. **Pavement Design, I.** Analysis and methods of measurement of surface properties related to vehicle performance; factors affecting pavement durability; traffic wear, climate, chemical action, combined effects; composition design of flexible and rigid pavements for proper surface properties, load carrying capacity, wear resistance, stability, and durability. 1 unit. Prerequisite: Civil Engineering 220 or equivalent. DANNER.

421. **Pavement Design, II.** Structural design of flexible and rigid pavements; loading characteristics, static, impact and repeated loads; load distribution through pavement layers, factors affecting distribution, methods of analysis;

evaluation of subgrade support; criteria for selecting design values. 1 unit. Prerequisite: Civil Engineering 220 or equivalent. Herrin.

426. **Traffic Planning.** Traffic engineering planning functions; urban and rural master traffic plans; traffic analyses for new or existing streets, highways, and terminal facilities. 1 unit. Prerequisite: Civil Engineering 325 or equivalent. Baerwald.

427. **Geometric Highway Design.** Highway classification; highway capacity; highway design controls; sight distance; horizontal and vertical alignment; cross section elements; highway types; controlled access highways; design of at-grade intersections, grade separations, and interchanges. 1 unit. Prerequisite: Civil Engineering 325 and 426, or consent of instructor. Baerwald.

428. **Traffic Engineering Operations.** Theory of traffic control; laws and ordinances; design and application of traffic control devices; special street designations; parking design and control; street illumination; miscellaneous traffic control designs. 1 unit. Prerequisite: Civil Engineering 325 and 426, or equivalent. Baerwald.

435. **Railway Construction and Maintenance.** Roadbed load capacity; economic design of track; advanced geometric design; economics of maintenance; grade crossing separations; review of specific projects. 1 unit. Prerequisite: Civil Engineering 335 or consent of instructor. Hay.

436. **Railroad Location and Operation.** Track and traffic capacity; optimum train size, performance, and scheduling; validity and accuracy of current practices; regional operating factors; optimum size of plant and modern location. 1 unit. Prerequisite: Civil Engineering 336 or consent of instructor. Hay.

440. **Theory of Water Treatment.** Properties of water and criteria of water quality; gas transfer operations in water treatment; chemical treatment processes; corrosion and corrosion control; sedimentation; filtration; disinfection; control of aquatic growths; control of tastes and odors. 1 unit. Prerequisite: Chemistry 122 and Microbiology 101. Ewing, O'Connor.

441. **Water Purification Laboratory and Design.** An extension of principles and application to experimental determination of design and operational criteria for various physical, chemical, and biological unit operations used in water purification processes. 1 unit. Prerequisite: Credit or registration in Civil Engineering 440 or consent of instructor. Austin, O'Connor.

442. **Theory of Waste-Water Treatment.** Composition, properties, and analysis of wastes; microbiology of waste treatment; pollution of natural waters; sedimentation; chemical treatment; aerobic and anaerobic treatment processes; disposal of waste sludges. 1 unit. Prerequisite: Chemistry 122 and Microbiology 101. Engelbrecht, Speece.

443. **Waste Treatment Laboratory and Design.** An extension and application to experimental determination of design and operational criteria for various physical, chemical, and biological unit operations used in waste treatment processes. 1 unit. Prerequisite: Credit or registration in Civil Engineering 442. Austin, Speece.

444. **Industrial Wastes.** Advanced considerations of industrial wastes problems of major waste-producing industries including the process producing the waste, waste composition, treatment methods, and inplant abatement techniques. ½ or 1 unit. Prerequisite: Civil Engineering 442 and 443, or consent of instructor. Engelbrecht, O'Connor.

445. **Fundamentals of Biological Treatment.** A detailed consideration of basic biological and chemical phenomena applied to aerobic and anaerobic treatment of aqueous wastes. 1 unit. Prerequisite: Credit or registration in Civil Engineering 443, or consent of instructor. ENGELBRECHT, SPEECE.

446. **Design of Water and Waste Treatment Plants.** A study of the fundamental factors affecting choice of treatment units and combination of unit processes into an integrated plant. 1 unit. Prerequisite: Civil Engineering 440, credit or registration in Civil Engineering 442, or consent of instructor. EWING, O'CONNOR.

447. **Radioactive Waste Disposal.** Same as Nuclear Engineering 447. Sources and characteristics of radioactive wastes; methods of treatment; ultimate disposal; fate of radioisotopes in the environment; permissible levels in air and water; current levels in water supplies; water treatment methods; monitoring techniques; solid waste disposal; gaseous wastes disposal; air monitoring; and reactor site selection and hazards evaluation. ½ or 1 unit. Prerequisite: Physics 282 or Chemistry 398 (Nuclear Engineering 398), or consent of instructor. AUSTIN, EWING.

450. **Advanced Hydrologic Analysis and Design.** Hydrologic cycle; hydrometeorology; collection of data; hyetograph and hydrograph analyses; infiltration and evapotranspiration studies; ground water exploration and recharge; statistical analyses; determination of waterway areas; flood routings; river and reservoir regulations; design and planning of flood control projects; and modern development such as radar weather, radioactive tracers, disposal of nuclear wastes, and electronic analogs. 1 unit. Prerequisite: Bachelor of Science in civil engineering, or consent of instructor. CHOW.

452. **Water Resources.** An advanced interdisciplinary course on water resources planning and development; geographic aspects; data collection; governmental functions; hydrologic implications; river hydraulics; hydraulic physical units and water quality; economic aspects; legal, political, and social problems; case studies. 1 unit. Prerequisite: Consent of instructor. CHOW and staff.

456. **Hydraulics of Surface Drainage.** Applications of hydraulics and hydrologic principles; elements of channel design, hydrologic determination of design flow, hydraulics of culverts and bridge openings, overland flow, flow in gutters and inlets, and hydrologic and hydraulic design of a bridge opening or culvert system. 1 unit. Prerequisite: Theoretical and Applied Mechanics 235 or equivalent. MCPHERSON.

457. **Ground Water.** An advanced interdisciplinary course on ground water; hydrogeology; hydrodynamics of flow through porous media; ground water hydrology; hydraulics of wells; hydraulic analysis of seepage; ground water pollution; ground water resources. 1 unit. Prerequisite: Consent of instructor. CHOW and staff.

458. **Open-Channel Hydraulics.** Basic hydromechanics; flow types; channel characteristics; flow-profile computations; hydraulic jump analysis; design of nonerodible, erodible, and grassed channels and transitional structures; study of supercritical flow and unsteady flow; modern developments in theory and design practice; application of numerical method, method of characteristics, method of singular points, and electronic digital computers and analogs. 1 unit. Prerequisite: Bachelor of Science in civil engineering or consent of instructor. CHOW, MURTHA.

460. Structural Analysis. Basic theory of indeterminate structures; deflections and displacements; continuous beams and frames; virtual work; qualitative and quantitative influence lines. 1 unit. Prerequisite: Bachelor of Science in engineering with a course in theory of simple structures. Gaylord, Oliver.

461. Structural Theory and Design. Advanced structural theory from the standpoint of design, analysis, and behavior, with particular emphasis on analysis; evaluation of methods of elastic analysis of structures; limit design and analysis; continuous beams and frames; multiple-story structures; space frames; arches. 1 unit. Prerequisite: Bachelor of Science in civil engineering; Civil Engineering 361 or 460, or equivalent. Hall, Stallmeyer.

462. Structural Theory and Design. Statically indeterminate trusses; continuous trusses; steel arches; secondary stresses, suspension bridges; long span roofs. 1 unit. Prerequisite: Bachelor of Science in civil engineering; Civil Engineering 361 or 460, or equivalent. Mosborg, Stallmeyer.

464. Reinforced Concrete Design. Theories of action of beams, slabs, and columns of reinforced concrete; codes and specifications and their influence on design; effect of continuity. 1 unit. Prerequisite: Bachelor of Science in engineering with courses in structures. Briscoe.

465. Structural Design in Metals. Theories of behavior of structural metal members and their components; interpretation of codes and specifications for the design of bridges and buildings. This course and Civil Engineering 475 form a unit in the study of theoretical and experimental investigations. 1 unit. Prerequisite: Bachelor of Science in engineering with courses in structures. Gaylord.

467. Behavior of Reinforced Concrete Structures. Ultimate strength and behavior of statically indeterminate reinforced concrete structures; applicability of elastic analysis to framed structures; analysis and design of floor slabs in buildings. 1 unit. Prerequisite: Civil Engineering 366. Siess.

468. Analysis and Design of Prestressed Concrete Structures. Principles of linear prestressing; the properties of materials used in prestressed concrete; service load and ultimate design of simply supported prestressed concrete beams; strength and behavior of prestressed concrete beams; composite sections; analysis, behavior, and design of continuous prestressed concrete beams. 1 unit. Prerequisite: Bachelor of Science in civil or architectural engineering with courses in reinforced concrete and in analysis of indeterminate structures. Khachaturian.

470. Statistical Theory of Structural Engineering. Study of the concepts and applications of probability and statistical theory in structural engineering and research, with emphasis on the scientific principles for considering fluctuations and randomness in physical phenomena and processes; mathematical modeling in structural mechanics including Monte Carlo simulation in structural systems analysis and design; engineering decision-making under uncertainty; analysis of loads and resistances; safety analysis of structures including system reliability prediction; introduction to stochastic structural dynamics. 1 unit. Prerequisite: Consent of instructor. Ang.

471. Numerical and Approximate Methods of Structural Analysis. Methods of successive approximations and numerical procedures for the solution of complex problems with applications to bridges, buildings, and aircraft structures: influence lines, moments and deflections of beams with axial load, buckling

strength of columns, moments and deflections of beams resting on elastic or plastic supports, vibration of beams, analysis of arches, moments and deflections of plates, other problems. 1 to 2 units. Robinson, Melin.

472. **Advanced Numerical Methods in Engineering.** Basic concepts in numerical and approximate methods: successive approximations, relaxation, finite differences, ordinary boundary value problems, initial value problems, partial differential equations, characteristic value problems, methods of interpolation, variational procedures. Special study of selected topics including vibrations of complex structures; blast, impact, and earthquake effects on structures; buckling and flexure of frameworks; torsion of solid and thinwalled sections; lateral buckling of beams; bending and buckling of plates and of stiffened plates; plane stress and axially symmetric problems in elasticity; other topics. 1 to 2 units. Prerequisite: Civil Engineering 471. Robinson, C. Yang.

473. **Analysis and Design of Plates and Shells.** Fundamental theories of bending and buckling of plates; practical application of theories in analysis and design of reinforced concrete bridge and building floors, highway and airport pavements, and structural plate components in metal; theory of shells with application to tanks, pressure vessels, shell roofs, and hipped plate construction. 1 to 2 units. Prerequisite: Consent of instructor. Schnobrich.

474. **Behavior of Structures Under Dynamic Loads.** Free vibrations, forced vibration, and transient response of structures and structural components having one or many degrees of freedom; analytical methods for the effects of wind load, explosion blast, impact, earth tremors, and other time-dependent excitations; effects of damping and inelastic action; propagation of stress waves; wind-induced vibrations with application to cables, pipelines, and tall stacks. 1 to 2 units. Prerequisite: Consent of instructor. Walker.

475. **Behavior of Steel Structures.** A critical evaluation of the actual behavior of metals, connections, members, and structures; the significance of this behavior in terms of design and the development of design specifications. This course and Civil Engineering 465 form a unit in the study of theoretical and experimental investigations. 1 unit. Prerequisite: Graduate standing in civil engineering or theoretical and applied mechanics. Chesson, Munse.

476. **Plastic Analysis and Design.** Inelastic behavior of metal structural frameworks; concept of the plastic hinge; collapse configurations; analysis of collapse mechanisms; requirements for stability; deflections, incremental collapse, shakedown; connections; optimum design; grid frameworks. 1 unit. Prerequisite: Civil Engineering 465 or consent of instructor. Gaylord.

477. **Design of Structures for Dynamic Loads.** Nature of dynamic loading from earthquakes and bomb blasts; nature of dynamic resistance of structural elements and complete structures; concepts of limit design; review of methods of analysis; significance and interpretation of results of analyses; criteria for design of blast-resistant structures; criteria for design of earthquake-resistant structures; application to actual problems. 1 unit. Prerequisite: Consent of instructor. Haltiwanger, Murtha, Newmark.

478. **Matrix Theory of Structural Mechanics.** Fundamental concepts of matrix calculus and its applications for a unified treatment of advanced structural mechanics and dynamics; basic calculus of matrices; iterative solution of systems of algebraic and differential equations; stress and structural analysis, method of tearing tensors; discrete simulation of continuous systems in higher

dimensions; eigen-value problems of discrete systems. 1 unit. Prerequisite: Civil Engineering 461 or 471, or consent of instructor. Ang.

479. Applied Structural Mechanics. Study of beams under lateral load; beams with combined lateral load and thrust; buckling; beams on elastic foundations; applications of Fourier series and virtual work principles to beam-type structures; stress and strain in three dimensions; applications to flexure of beams and plates and to constrained torsion; elements of the engineering theory of plates. 1 unit. Prerequisite: Mathematics 345 and one undergraduate course in statically indeterminant structures, or consent of instructor. Robinson.

480. Earth Pressures and Retaining Structures. Classical and modern earth pressure theories and their experimental justification; pressures and bases for design of retaining walls, bracing of open cuts, anchored bulkheads, cofferdams, tunnels, and culverts. 1 unit. Prerequisite: Credit or registration in Civil Engineering 384. Ireland, Kane.

481. Earth Dams and Related Problems. Fundamentals of problems of slope stability; seepage in composite sections and anisotropic materials; methods of stability analysis; mechanism of failure of natural and artificial slopes; compaction; field observations. 1 unit. Prerequisite: Credit or registration in Civil Engineering 384, or consent of instructor. Ireland, Peck.

482. Measurement of Soil Properties. Laboratory and field work in soil sampling, classification, and testing; experimental studies of modern soil mechanics parameters and theories with emphasis on applications to design problems. Experiments include permeability, consolidation, direct shear, and triaxial shear. The research approach is used to point out interpretations and limitations of data in practice. 1 unit. Prerequisite: Credit or registration in Civil Engineering 383, or consent of instructor. Olson.

483. Soil Mechanics. Advanced studies of research techniques in soil mechanics and foundation engineering. 1 unit. Prerequisite: Civil Engineering 384 or consent of instructor. Olson.

484. Foundation Engineering. Critical study of case histories of projects in foundation engineering; current procedure for design and construction of foundations, embankments, and waterfront structures. 1 unit. Prerequisite: Civil Engineering 384. Ireland, Peck.

485. Soil Engineering for Transportation Facilities. Problems of soil classification; evaluation of stability of natural and compacted soils as subgrades, slopes, and embankments; effect of climate, soil properties, compaction, and admixtures on subgrade stability. 1 unit. Prerequisite: Civil Engineering 383 or equivalent. Liu, Thornburn.

494. Municipal Administration and Engineering. Legal authority of municipalities, forms of municipal government; municipal functions, organization, and management; city finance; engineering functions of city government; city planning and zoning; building codes and inspection; street lighting; public utilities; city cleaning; recreational development. 1 unit. Prerequisite: Bachelor of Science in civil engineering or consent of instructor. Danner.

495. Civil and Sanitary Engineering Seminar. Discussion of current topics in civil and sanitary engineering and related fields by staff, students, and visiting lecturers. Course may be repeated. 0 or ¼ unit.

497. Special Problems. Individual investigations or studies of any phase of civil engineering selected by the student and approved by his adviser and the

staff member who will supervise the investigation. 0 to 4 units. Prerequisite: Consent of instructor.

499. **Thesis Research.** 0 to 4 units.

Suggested Topics for Civil Engineering 497 — Special Problems

A sufficient number of regular courses have been established to cover adequately some phases of civil engineering. Even in these, students may wish to take advantage of Civil Engineering 497 for special studies. In other phases, extensive use is made of Civil Engineering 497 to cover subjects not now included in the regular courses. The following topics are suggested as being typical in those areas noted, but registration is not restricted to these topics.

HIGHWAY AND TRAFFIC ENGINEERING

Highway Transportation
Highway Organization and Management
Highway Economics and Finance
Highway Laws and Regulations
Traffic Records and Accident Analyses
Highway Planning and Programming
Properties and Performances of Aggregates
Properties of Bituminous Materials and Mixes
Pavement Analysis and Behavior
Highway Material Stabilization
History and Development of Highways
Roadway Location and Design
Highway Maintenance and Operation
Analyses of Traffic Problems

HYDRAULIC ENGINEERING

Hydromechanics
Water Wave Mechanics
Watershed Hydraulics
Hydrologic Systems
Hydrometeorology
Erosion and Sedimentation
Coastal Engineering
Drainage and Flood Control
Irrigation
Water Power Engineering
Dam and Reservoir Design
Operations Research in Water Resources Planning and Development

RAILWAY ENGINEERING

Relation Between Track and Rolling Stock
Rail Design and Defects
Track and Roadway Structures
Technological Development of Railroads
Turnout Design and Use
Problems in Railway Management
Grade Crossing Protection and Separation
Economics of Train Make-up and Operation

GENERAL TRANSPORTATION

Transportation Planning
Design of Transport Systems
Urban Transit Planning and Design
Environmental Factors in Transportation
Technological Development of Transport Media
New and Minor Transport Media
Selected Transportation Problems
Waterways
Airways
Pipelines

SANITARY ENGINEERING

Stream Pollution
Water Quality
Industrial Wastes
Biological Aspects
Air Pollution
Industrial Hygiene and Occupational Health
Radiological Health
Refuse Collection and Disposal

PLAIN CONCRETE

Nature of the Constituent Materials of Concrete
Nature of Cement Gel
Quality Control and Specifications
Durability of Concrete
Creep and Relaxation of Concrete
Fatigue and Fracture of Concrete

SOIL AND ROCK MECHANICS

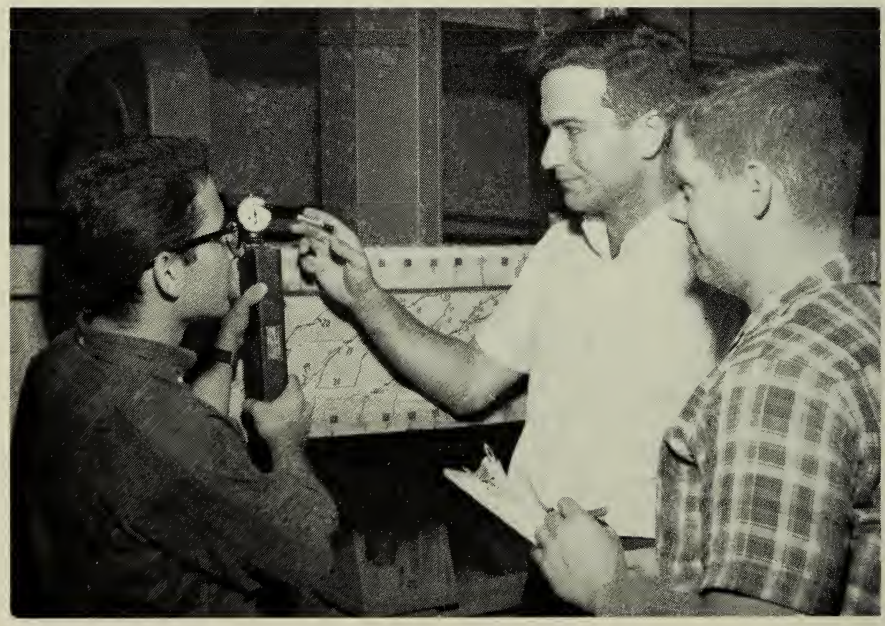
Soil and Rock Dynamics

Soil-Structure Interaction Problems
Analysis of Field Data
Physico-Chemical Properties of Soils
Soil Stabilization
Fundamentals of Rock Mechanics
Laboratory and Field Measurement of Rock Properties
Rock Mechanics Applied to Civil Engineering

STRUCTURAL ENGINEERING

Applied Structural Mechanics
Matrix Structural Methods
Limit Design
Probability Aspects
Structural Theory
Structural Instability
Thin Shell Structures
Structural Dynamics
Prestressed and Reinforced Concrete Structures
Riveted, Bolted, and Welded Joints
Fatigue and Fracture of Metal Structures

Professor M. A. Sozen, center, and two graduate students examine a prestressed concrete beam following a test-to-failure study.



SURVEYING AND PHOTOGRAMMETRY

Analytical Photogrammetry
Terrestrial Photogrammetry
Interpretation of Aerial Photographs
Adjustment of Observations
Geodetic Surveying
Cadastral Engineering
Cartographic Surveying
Route and Construction Surveying

Selected Courses Offered in Other Departments[1]

CHEMISTRY

321. Chemical and Instrumental Analysis. Chemical and instrumental methods of analysis and their application to the quantitative study of chemical reactions. ¾ to 1¼ units. Prerequisite: Chemistry 336 and 340 or 342 with registration in Chemistry 343 and 344.

322. Analytical Separations and Experimental Design. Quantitative study of separations by chemical and instrumental analytical methods. Application of statistics to separation methods, to experimental design, and to interpretation of experimental data. ¾ unit. Prerequisite: Chemistry 321 or equivalent.

340. Principles of Physical Chemistry. A one-semester course in physical chemistry emphasizing topics most important to students in the biological and agricultural sciences. Not open to students in the specialized curricula in chemistry or chemical engineering. 1 unit. Prerequisite: Physics 102; Chemistry 122 and 133, or equivalent; Mathematics 132 or equivalent.

350. General Biochemistry. The chemistry and reactions of constituents of living matter, including carbohydrates, lipids, proteins, nucleic acids, vitamins, coenzymes, and minerals; the chemistry and regulation of the reactions and processes of whole organisms, plant and animal, of organs, cells, and subcellular particles and soluble components. Lectures and assigned readings. ¾ unit. Prerequisite: Quantitative analytical chemistry, and Chemistry 133 or 234, or equivalent; registration in Chemistry 355.

355. Biochemistry Laboratory. To accompany Chemistry 350. An introduction to experimentation with biochemical systems, processes, and compounds of biochemical importance; identification and quantitative measurement of constituents and transformations in biological systems. Laboratory, quizzes, and assigned readings. Required of all students who expect to take advanced courses in biochemistry. ¾ unit. Prerequisite: Quantitative analytical chemistry, Chemistry 133 or 234, or equivalent; registration in Chemistry 350.

397. Radiochemistry. Same as Nuclear Engineering 397. ¾ unit. Prerequisite: One semester of physical chemistry or consent of instructor.

398. Radiochemistry Laboratory. Same as Nuclear Engineering 398. To accom-

[1] Courses numbered in the 300 series are open to advanced undergraduates and graduate students and those numbered in the 400 series are open to graduate students only.

pany Chemistry 397. ½ unit. Prerequisite: One semester of physical chemistry or consent of instructor.

450. **Chemistry of Biological Processes.** A consideration at the molecular level of biological processes including bioenergetics, biosynthetic and degradative pathways of cellular components, metabolic regulation and enzyme reaction mechanisms. 1 unit. Prerequisite: Chemistry 350 and 355.

ECONOMICS

372. **Operations Research.** Introduction to methods of operations research from an executive or managerial viewpoint, emphasizing formulation of business problems in quantitative terms. Industrial applications of linear programming, dynamic programming, game theory, probability theory, queueing theory, and inventory theory. ½ or 1 unit. Prerequisite: Economics 170 and Management 101, or consent of instructor.

400. **General Economic Theory.** Emphasis in this course is placed on micro-economic theory. The principal topics include: a review of value and distribution theory, the theory of choice by households and firms, general micro-economic theory, and theoretical developments of current interest. Attention is given to empirical studies intended to affirm or disaffirm economic principles. Intended for minors in economics and others who have a minimum preparation for graduate study in economics. 1 unit. Prerequisite: Economics 102, 103, or 108.

401. **General Economic Theory.** Emphasis in this course is placed on macro-economic theory and the relationship of economics to the other social sciences. The principal topics include: a review of Keynesian macro-economic theory, formal growth theory, selected business cycle theory, the theory of socio-economic change, and an outline of the differentiation and integration of economics and other social sciences. Intended for minors in economics and others who have a minimum preparation for graduate study in economics. 1 unit. Prerequisite: Economics 102, 103, or 108.

414. **Public Finance.** An analysis of the economics of public expenditures, administration of public funds, intergovernmental fiscal relations, nontax revenues, public borrowing, debt management, and fiscal policy. 1 unit. Prerequisite: Six hours of economics.

415. **Economics of Taxation.** An analysis of the economics of taxation, with respect to distribution of tax burden, incidence of taxation, and the place in the tax system of the major taxes, particularly the personal and corporation income, sales and excise, property, and death taxes. 1 unit. Prerequisite: Six hours of economics.

440. **Labor Economics.** Same as Labor and Industrial Relations 440. A survey of recent trends in the labor force, of real and money earnings, and of the distribution of national income. This review of recent trends in these areas is used as the basis for a critical economic analysis of contemporary English and American wage theory. 1 unit. Prerequisite: A minimum of six hours of economics.

441. **Labor Economics.** Same as Labor and Industrial Relations 441. The economic issues and implications involved in hours of work, employment and unemployment, and trade union institutionalism (the impact of the trade union

upon the basic institution of a free enterprise economy). Emphasis in all cases is upon the development of appropriate public policy. 1 unit. Prerequisite: A minimum of six hours of economics.

470. Economic Statistics. Basic concepts and methods of statistical analysis as applied in economics and business. 1 unit. Prerequisite: Consent of instructor.

474. Operations Analysis. A study of mathematical and statistical techniques used to provide management with information on which to base decisions. Mathematical programming, dynamic programming, queueing theory, renewal theory, and Monte Carlo methods are applied to problems of the individual firm. Techniques and problems are related to principles of economics and the theory of the firm. 1 unit. Prerequisite: Mathematics 359 or equivalent.

484. Economics of Transportation. A study of the principal economic problems arising in connection with the development and regulation of railroads and other modes of transport. 1 unit.

485. Economics of Transportation. A study of the principal economic problems arising in connection with the development and regulation of railroads and other modes of transport. 1 unit.

GENERAL ENGINEERING

360. Engineering Applications of Meteorological Fundamentals. The application of the fundamentals of meteorology to engineering problems including the transport and diffusion of particulate matter, aerosols, and gasses; precipitation processes and rainout; behavior of stack effluents, explosion debris, and radioactive materials in the atmosphere. Applications to operation scheduling and to site selection. 1 unit. Prerequisite: Mathematics 142 or 143; Physics 106, 107, and 108; Mechanical Engineering 205 and 206, or 209, or Chemistry 342 and 344, or Physics 360.

GEOGRAPHY

313. Climates of the Continents. A regional treatment of the climates of the world by continents. ¾ unit. Prerequisite: Geography 101 and 111.

373. Map Compilation and Construction. Laboratory instruction and practice in the basic techniques of map making, followed by a consideration of problems involved in the construction of maps for presentation in a reproduced form (i.e., printed, photographed). Included are the selection of proper source materials for the base and body of the map, the compilation and correlation of these materials, and methods of mechanical and photographic reproduction. 1 unit. Prerequisite: Consent of instructor.

378. Descriptive Interpretation of Aerial Photographs. Reading and interpreting of aerial photographs; their potentialities and limitations as a research tool of geography. 1 unit. Prerequisite: Consent of instructor.

383. Urban Geography. The distribution, functions, and internal structure of cities; a geographic analysis and classification of urban centers and their tributary areas. 1 unit.

412. Analytical Climatology. A detailed consideration of the character and causes of the climates of certain selected areas; the application of various criteria as bases for climatic differentiation. 1 unit. Prerequisite: Geography 111; Geography 313 or equivalent; consent of instructor.

473. **Problems in Cartography.** Subjects for map presentation are selected in the student's field of specialization or area of interest. Data are collected and maps compiled and carried to completion in final drafted form suitable for publication. 1 unit. Prerequisite: Geography 373 or consent of instructor.

495. **Advanced Studies in Geography.** Directed and supervised detailed investigation of selected problems or regions. Designed to develop ability to conduct independent investigation. ½ to 2 units. Work may be taken in Urban Geography.

GEOLOGY

301. **Geomorphology.** The study of the history, origin, and characteristics of land forms produced by fluvial, glacial, wind, and wave erosion, or by a combination of these, acting upon the major kinds of geologic materials and structures. Lectures, laboratory, and field trips. 1 unit. Prerequisite: Geology 102.

450. **Geology for Civil Engineers.** Advanced physical geology, with emphasis on the geological aspects of civil engineering. 1 unit. Prerequisite: Geology 150 or equivalent.

493. **Advanced Studies in Geology.** ½ to 2 units. Work to be taken in Engineering Geology.

INDUSTRIAL ADMINISTRATION

401. **Scientific Management — Qualitative.** A study of modern management principles, function, processes, and activities, with major emphasis upon developing a scientific body of administrative knowledge. 1 unit. DAUTEN.

402. **Scientific Management — Quantitative.** A study and analysis of the quantitative techniques and controls available to modern management, with major emphasis upon integrating qualitative and quantitative management concepts. 1 unit.

MATHEMATICS

315. **Linear Transformations and Matrices.** 1 unit. Prerequisite: One year of calculus.

341. **Differential Equations.** 1 unit. Prerequisite: One year of calculus.

342. **Differential Equations.** 1 unit. Prerequisite: Mathematics 341.

343. **Advanced Calculus.** 1 unit. Prerequisite: One year of calculus.

345. **Differential Equations and Orthogonal Functions.** Prerequisite: One year of calculus.

346. **Complex Variables and Applications.** For students who desire a working knowledge of complex variables. Covers the standard topics and in addition gives an introduction to integration by residues, the argument principle, conformal maps, Laplace transforms, and potential fields. Students desiring a systematic development of the foundations of the subject should take Mathematics 348. 1 unit. Prerequisite: Mathematics 343 or consent of instructor.

363. **Advanced Statistics.** 1 unit. Prerequisite: One year of calculus.

364. **Advanced Statistics.** 1 unit. Prerequisite: Mathematics 363.

381. Vector and Tensor Analysis. 1 unit. Prerequisite: Mathematics 343, or equivalent, or consent of instructor.

382. Vector, Tensor, and Matrix Methods in Applied Mathematics. 1 unit. Prerequisite: Mathematics 381 or consent of instructor.

386. Laplace Transforms. 1 unit. Prerequisite: Mathematics 343.

387. Introduction to Numerical Analysis. 1 unit. Prerequisite: Senior standing, calculus, and a course in differential equations, or consent of instructor.

388. Mathematical Methods in Engineering and Science. 1 unit. Prerequisite: Mathematics 343.

395. Advanced Programming. This course is devoted to a discussion, by means of classroom and laboratory examples, of the efficient use of computers for solving problems. Particular emphasis is given to examples in which limitations of computers have been overcome. 1 unit. Prerequisite: Mathematics 195 and senior standing, or consent of instructor.

397. Mathematical Theory of Data Processing. Mathematical structure and automatic processing of extensive files of data are developed employing methods from statistics, graph theory, and information theory. Topics discussed include: the selective screening and classification of data (pattern recognition, machine abstracting, optimum encoding, least square adjustment of data); and file organization and maintenance (information retrieval, indexing, scheduling). 1 unit. Prerequisite: Mathematics 195, or consent of instructor.

444. Partial Differential Equations. 1 unit. Prerequisite: Consent of instructor.

455. Mathematical Methods of Physics. 1 unit. Prerequisite: Mathematics 348.

457. Analytical Problems in Numerical Analysis. A study of the various mathematical problems arising when one formulates problems in analysis, such as the solution of ordinary or partial differential equations, for treatment by an automatic digital computer. Among the problems discussed are convergence of difference equations to differential equations, and stability of methods for approximately solving ordinary and partial differential equations. 1 unit. Prerequisite: Mathematics 387 or consent of instructor.

458. Numerical Integration of Differential Equations. Existence theory of Picard; Lagrangian integration methods; absolute and relative stability; Schur's theorem; integration of systems; orthogonal polynomials; Gauss quadrature; Tschebycheff quadrature and Bernstein's theorem; special methods for initial value problems. 1 unit. Prerequisite: Mathematics 455 or consent of instructor.

MICROBIOLOGY

309. Cultivation and Properties of Microorganisms. Nutritional and metabolic properties of the major groups of microorganisms; a comparative study of the ecology, selective isolation, cultivation of bacteria, and microbiological essays. 1 unit. Prerequisite: Organic chemistry, with biochemistry recommended.

330. Advanced Microbiology. Modern contributions to the science of microbiology, including considerations of the micro- and macro-molecular anatomy of the bacterial cell, the physiological and genetic behavior of microorangisms, and the role of bacterial viruses as agents involved in the transfer of genetic information. Lecture. ¾ unit. Prerequisite: Microbiology 101 or 201, or

equivalent; credit or registration in biochemistry or consent of instructor; calculus strongly recommended.

420. **Chemistry of Microbic Processes.** The properties of microorganisms with emphasis on the metabolic pathways and chemical processes involved in the release of energy in the dissimulation of substrates by fermentation and respiration, and in the synthesis of cellular constituents. The metabolic types represented by microorganisms including the heterotrophic, autotrophic, and photosynthetic patterns are included. ¾ unit. Prerequisite: Microbiology 309 or 330 and Chemistry 234 and 350, or equivalent; consent of instructor.

NUCLEAR ENGINEERING

347. **Introduction to Nuclear Engineering.** Nuclear particles and nuclear chain reactions, energy release from fission; classification of nuclear reactors; fast and thermal reactors; reactor theory; slowing down and diffusion of neutrons; radiation shielding; materials of construction, radiation damage; reactor instrumentation, safety, and control; chemical processing of nuclear materials. ¾ or 1 unit. Prerequisite: Physics 282 or 382 and senior standing in engineering, or consent of instructor.

349. **Fundamentals of Radiation Protection.** Same as Civil Engineering 349. ¾ or 1 unit. Prerequisite: Nuclear Engineering 397, or Physics 382, or equivalent.

397. **Radiochemistry.** Same as Chemistry 397. Properties of radioactive nuclei, nature of radioactivity, nuclear structure, nuclear reactions, and interactions of radiations with matter, chemical aspects of radioactivity work, and application of nucleonics to chemistry. ¾ unit. Prerequisite: One semester of physical chemistry or consent of instructor.

398. **Radiochemistry Laboratory.** Same as Chemistry 398. Radioactivity detection and tracer applications of radioisotopes in chemistry and other fields. One laboratory and one discussion period per week. ½ unit. Prerequisite: One semester of physical chemistry or consent of instructor.

401. **Fundamentals of Nuclear Engineering.** A lecture and problem course to provide background for further work in nuclear engineering. Problems in materials, heat transfer, and fluid flow. Special emphasis is given to basic ideas and the mathematical similarity of problems in heat transfer, fluid flow, and neutron diffusion. 1 unit. Prerequisite: Physics 282 or 382 and Mathematics 345, or equivalent, or consent of instructor.

441. **Nuclear Radiation Shielding.** Radiation units and measurement; tolerance limits; interaction of radiation and matter; geometry factors in attenuation; gamma ray and neutron attenuation; moment theory for attenuation; application to reactors, protective shelters, and space vehicles. 1 unit. Prerequisite: Nuclear Engineering 347, Mathematics 343 and 345, or consent of instructor.

451. **Reactor Laboratory.** Reactor operation: start-up, changes in power level, and shutdown. Reactor instrumentation; subcritical assemblies; flux measurements in core and thermal column; control rod worth measurements; effects of changes in fuel configurations; activation and neutron beam experiments. ½ or 1 unit. Prerequisite: Consent of instructor.

458. **Nuclear Reactor Engineering.** Development of engineering design phases of the fission chain reactor: reactor materials and radiations, thermal aspects, heat removal, radiation hazards, shielding, reactor performance, controls and

instrumentation, types and applications, fuel conversion, reactor power economics. 1 unit. Prerequisite: Consent of instructor.

PHYSICS

321. Theoretical Mechanics. Motion of a particle in one, two, and three dimensions with applications; Kepler's laws and planetary motion; scattering of particles; conservation laws; motion of a rigid body in two dimensions; statics of extended systems. Lectures and problems. 1 unit. No credit for graduate physics majors. Prerequisite: General physics; registration in Mathematics 341, 345, or 349.

322. Theoretical Mechanics. Continuation of Physics 321. Moving coordinate frames, fictitious forces; special theory of relativity, conservation laws, particle motion and creation; rigid body motion in three dimensions; gravitation and earth motion; generalized coordinates and Lagrange's equations; constraints, small vibrations. 1 unit. Prerequisite: Physics 321.

382. Nuclear Physics. A lecture and problem course presenting our modern knowledge of the properties of nuclear particles, natural and artificial radioactivity, laboratory equipment for producing and studying high energy particles, nuclear disintegrations, the interaction of nuclear particles with each other and with matter, cosmic rays, mesons, and recent developments in high energy nuclear physics, and the application of nuclear phenomena to some practical problems. 1 unit. Prerequisite: Physics 381 or 383.

383. Atomic Physics and Quantum Theory for Engineers. Introduction to the basic concepts of quantum theory which underlie modern theories of the properties of materials. Topics covered include elements of atomic and nuclear theory, kinetic theory and statistical mechanics, quantum theory, and simple applications, atomic spectra and atomic structure, molecular structure and chemical binding. Lectures and problems. ¾ or 1 unit. Prerequisite: General physics; general chemistry; Mathematics 345 or equivalent.

PHYSIOLOGY

301. General Physiology. Same as Zoology 301. A consideration from the standpoint of experimental biology of functions that are common to most living organisms. 1 unit. Prerequisite: One year each of college-level biology, mathematics, and physics; chemistry through organic.

331. General Radiobiology. Responses of multicellular organisms, cells, and macro-molecules to ionizing radiations. Lectures, student reports, and discussions. 1 unit. Prerequisite: One year each of mathematics, physics, chemistry, and biology.

462. Experimental Bioclimatology. Same as Geography 462. Laboratory work and demonstrations on methods of measuring meteorological factors, of clinical thermometry, and partitional calorimetry; laboratory work on physiological adjustments of man to heat, cold, and high altitude. ½ unit. Prerequisite: Physiology 301, or 401 and 402; credit or registration in Physiology 461.

POLITICAL SCIENCE

406. Municipal Administration. Position of cities in American governmental sys-

tems; governmental interrelationships; powers; services; current municipal problems. 1 unit.

SOCIOLOGY

385. **Social Statistics, I.** Deals intensively with descriptive statistics, probability, statistical inference, and significance testing by means of both parametric and nonparametric tests, and the various measures of association. 1 unit. Prerequisite: Sociology 185 or Mathematics 122 or 123, or consent of instructor.

476. **Urban Communities and Urbanization.** Intensive study of special aspects of the urbanization process as it affects the life of communities in this and in other countries. 1 unit.

THEORETICAL AND APPLIED MECHANICS

311. **Mechanical Vibrations.** Kinematics of vibratory motion; comprehensive study of motion having single degree of freedom; critical speeds of shafts; vibration of systems with several degrees of freedom. Applications to engineering problems. ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 154, 156, or 211 and 221.

314. **Advanced Dynamics for Engineers.** Three-dimensional kinematics of a rigid body, general dynamics of a rigid body, moments and products of inertia, kinetic energy, rotation of a rigid body about a fixed axis and about a fixed point, Euler equations of motion, gyroscopic theory; introduction to Lagrange equations; engineering applications. 1 unit. Prerequisite: Theoretical and Applied Mechanics 211 or equivalent; Mathematics 341 or 345.

315. **Advanced Dynamics with Applications to Engineering Problems.** General advanced methods of dynamics are discussed. Some emphasis is placed on the behavior of special components of guidance and control systems. Associated engineering problems are treated. Topics: Lagrange equations and Hamiltonian canonical equations. Hamiltonian methods; theory of vibrations; special theory of relativity, gyroscopic compass; gyroscopic stabilizer; modern gyroscopes, astronomical applications. 1 unit. Prerequisite: Theoretical and Applied Mechanics 314 or equivalent.

321. **Advanced Mechanics of Deformable Bodies.** Basic concepts of mechanics of deformable bodies and brief review of elementary topics; theory of stress and strain at a point; theories of failure, including failure by fracture; unsymmetrical bending; curved beams; torsion of noncircular sections; energy principles, Castigliano's Theorem. ½ or 1 unit. Prerequisite: Theoretical and Applied Mechanics 221 and 223 or 224.

326. **Experimental Stress Analysis.** Measurement of stresses or deformations that are of significance in the engineering design of load-resisting members; use of optical, electrical, and mechanical instrumentation, models, analogies, brittle coatings, electrical resistance gauges, photoelasticity, etc. ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 150, 211, 221, and 223 or 224. Theoretical and Applied Mechanics 321 is desirable.

334. **Fluid Mechanics and Advanced Hydraulics.** A study of the basic properties of fluids in general, particularly those that influence the flow of fluids in pipes and open channels, viscosimetry, dimensional analysis, effect of boundary conditions, cavitation, water tunnel, hydraulic jump, water hammer, pumps,

turbines. Some laboratory work. ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 235.

335. Dynamics of Fluids. An intermediate course in the mechanics of fluids, introducing analytical methods of solution for ideal and real fluids. Potential flow theory, theoretical approaches to viscous flows including boundary-layer theory, and the analysis of compressible flows are indicated. ¾ or 1 unit. Prerequisite: Theoretical and Applied Mechanics 235.

346. Dimensional Analysis and Theory of Models. The nature and use of dimensions, systematic calculation of dimensionless products, algebraic theory of dimensional analysis, similarity and model laws, and derivation of model laws from differential equations. Applications include von Karman's theory of similarity in turbulent flow, boundary layer theory, topics in open channel flow, model laws for pumps and turbines, topics in structural analysis and vibration theory, topics in the theory of heat. ½ to 1 unit.

351. Advanced Mechanics of Continuous Media. General theory of stress; general theory of strain, stress-strain relationships; plane theory of elasticity; advanced topics in bending and torsion. 1 unit. Prerequisite: Theoretical and Applied Mechanics 221; Mathematics 343; a course in differential equations.

400. Seminar in Engineering Mechanics. There are many special topics in the field of mechanics such as fracture of metals, creep of materials, etc., in mechanics of solids; fluid flow problems such as the nature of turbulence, boundary layer theory, nature and effects of roughness of boundary, effects of free surface; dynamics problems such as vibration of beams with moving loads, the gyroscope, etc. Such special topics as these are covered in this course. Each semester one or more of these topics is selected and announced as the area to be covered in this course during that semester. ¼ unit.

412. Vibration Analysis. Continuation of Theoretical and Applied Mechanics 311. Specific topics are systems of several degrees of freedom; applications of generalized coordinates and Lagrange's equations; boundary value problems in vibration of elastic bodies, including strings, rods, and beams; Stodola's method; iteration process and matrix procedure; vibrations in reciprocating machines, airplane structures and propellers; impact and transient vibrations; self-excited vibration; stability; non-linear systems. 1 unit. Prerequisite: Theoretical and Applied Mechanics 311.

416. Energy Principles in Engineering Mechanics. Designed to introduce the student to the variational principles of mechanics and their applications to engineering problems. The derivation, interpretation, and applications of the principle of virtual displacements, the principle of minimum potential energy, the principle of complementary energy, Castigliano's theorem, Hamilton's principle, and Lagrange's equations of motion constitute the main part of the course. Variational methods of approximation are treated briefly. The material includes numerous illustrative applications to stress analysis of statically determinate and statically indeterminate frames, problems of elastic stability, the theories of rings and curved beams, the theory of elastic plates, vibrations of structures, and wave motions. 1 unit. Prerequisite: Theoretical and Applied Mechanics 451.

424. Properties of Engineering Materials. Structure of metals and behavior of materials under various conditions of loading and use, including static, creep, fatigue and impact; effects of high and low temperature, strain rate, state of

stress, and internal structure; criteria of failure; relation of mechanical properties to behavior; significance of mechanical properties; tests and interpretation of test data; material specifications. ½ to 1 unit.

425. **Mechanics of Inelastic Bodies.** The course presents methods of obtaining relations between loads, deformations, stresses, and strains in various members that are stressed beyond the elastic range. Most applications consider both time independent and time dependent (creep) inelastic deformations. Some specific topics are straight and curved beams, columns and beam-columns, fully plastic analysis of statically indeterminate members and structures, torsion of circular and noncircular bars, and torsion-tension of bars of circular cross-section. ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 321.

426. **Stress and Deformation in Engineering Components.** Continuation of Theoretical and Applied Mechanics 321. Energy principles; forces and moments in plane and three-dimensional indeterminate members; beams on elastic support; flat plates, thick-walled cylinders, rotating disks, including temperature stresses; contact stresses and deflections; values and significance of stress concentrations. ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 321 or equivalent.

427. **Theories of Mechanical Properties and Behavior of Plain Concrete.** Theories used in the design of concrete and the factors affecting the properties and behavior of the material and of the test piece. Behavior of plain concrete under different types of environment and of loading, such as long time, repeated, and triaxial are emphasized. The studies involve critical reviews of experimental and analytical investigations. ½ to 1 unit. Prerequisite: Bachelor of Science degree in engineering.

428. **Analysis of Nonlinear Systems.** Same as Electrical Engineering 428. Singular points and stability considerations are treated. Graphical and analytical methods including the perturbation method, variation of parameters, Galerkin's method, and the Ritz method for solving nonlinear differential equations are considered. 1 unit. Prerequisite: Mathematics 341 and consent of instructor.

431. **Theory of Ideal Fluid Flow.** Together with the following course, topics in advanced fluid mechanics are covered that are the basis of many modern developments. Ideal fluid theory is concerned with an incompressible fluid of negligible viscosity. The differential equations of motion are derived and the several methods of obtaining flow solutions are presented: the obtaining of velocity potentials and stream functions by superposition of the effects of source, doublets, and vortices, and by the methods of conformal mapping. Relations for finding the resultant forces and moments on bodies are derived and applied to bodies such as lifting surfaces. Other topics covered include the theory and application of free streamline flows, vortex motions, and surface wave theory. 1 unit. Prerequisite: An elementary course in fluid flow and a course in advanced calculus.

432. **Theory of Flow of Viscous Fluids.** Although a logical continuation of Theoretical and Applied Mechanics 431, this course need not be taken sequentially. Concerned with the theoretical development, analysis, and solution of incompressible viscous fluid flow problems. Starting with the stress relations occurring in viscous fluids, the differential equations of motion are derived and direct and approximate solutions for laminar flows are

developed. Boundary-layer theory is presented and the occurrence of turbulence and its characterization introduced. The basic equations for analyzing turbulence flows are introduced and approximate solution for flows in boundary-layers with and without pressure gradients (and separation) pipes and jets are presented. Includes consideration of experimental observation and application to technological problems. 1 unit. Prerequisite: An elementary course in fluid flow and a course in differential equations.

441. Applied Analysis in Engineering. A course to provide training in applications of mathematics to engineering problems. Most of the illustrations are taken from engineering mechanics. 1 unit. Prerequisite: Mathematics 143; Mathematics 343 and 345 are recommended.

442. Applied Analysis in Engineering. Continuation of Theoretical and Applied Mechanics 441. 1 unit. Prerequisite: Mathematics 143; Mathematics 343 and 345 are recommended.

451. Theory of Elasticity with Application to Engineering Problems. A study of the mechanics of elastic deformable bodies, based on the fundamental concepts of equilibrium, geometry of strain, and properties of materials. Relations between stresses, strains, and displacements are studied in detail with special consideration given to their significance in engineering problems. 1 unit. Prerequisite: Mathematics 343; Mathematics 341 or equivalent.

452. Theory of Elasticity with Application to Engineering Problems. Continuation of Theoretical and Applied Mechanics 451. 1 unit. Prerequisite: Theoretical and Applied Mechanics 451.

454. Theory of Shells. A course designed to provide the theoretical basis of stress analysis of shell-type structures, such as ships, submarines, monocoque aircraft structures, concrete roofs and domes, pressure vessels, and containers for liquids. The material includes the differential geometry of shell theory, equilibrium equations, momentless theory of shells, strains in shells, statically indeterminate problems of shells, energy formulations, and stability of shells. 1 unit. Prerequisite: Theoretical and Applied Mechanics 451.

457. Classical Elastostatics. A modern unified treatment of the concepts and techniques developed in the course of investigation of the Cauchy-Navier equations. Emphasis is placed on the interpretation and motivation of ideas and their interrelation for the solution of three-dimensional problems. Topics covered are the classical boundary value problems, existence and uniqueness theorems, stress functions and displacement potentials, singular states of stress, extension of Green's method to the equations of elasticity, method of series, and approximation techniques. The course represents a preparation for (1) students interested in the current state of knowledge in classical elasticity, and (2) students intending to do their doctoral dissertations in classical elasticity. 1 unit. Prerequisite: Theoretical and Applied Mechanics 451 or equivalent; Consent of instructor.

458. Wave Motion in Continuous Media. An analysis of the dynamics of deformable bodies with a major emphasis on elastic media. Introduces the terminology associated with and the methods for treating such problems. Includes a general discussion of the motion of strings, bars, shafts, plates, and other bodies when subjected to load. Detailed examination of approximations involved is made and their engineering significance is discussed. 1 unit. Prerequisite: Theoretical and Applied Mechanics 311, 314, 451; Mathematics 341, 342, 343, or equivalent.

460. **Continuum Mechanics.** Foundations of the general (nonlinear) theories of continuum mechanics. A brief introduction to the tensor calculus is followed by a thorough discussion of the theory of deformation and motion of continua. The stress principle of Cauchy and the basic principles of classical mechanics, i.e., balance of momentum, moment of momentum, and energy, are discussed. A general treatment of constitutive relations is followed by detailed examination of some examples for two particular materials, the elastic solid and the stokesian fluid. 1 unit. Prerequisite: Theoretical and Applied Mechanics 351 or equivalent.

462. **Theory of Plasticity.** The physical and mathematical formulation of the mechanics of inelastically deformed bodies, plastic stress-strain laws, and their association with yield and loading functions. Deals primarily with members subjected to biaxial and triaxial stress conditions. Specific topics include applications to flexure and torsion of prismatic members; expansion of thick-walled cylinders and spherical shells; introduction to problems in plane plastic flow and variational plasticity. ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 451 or equivalent.

464. **Theory of Buckling.** The pertinent information and theoretical background required for the prediction of failure by buckling of structures such as airplanes, ships, bridge trusses, fabricated towers and shells, practical illustrations. Specific topics are elastic columns with various end restraints; buckling of frameworks, arches, rings, and plates; inelastic buckling of columns and plates; lateral buckling of beams; energy theory; Ritz procedure; Euler's equation of the calculus of variations. ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 416 and 451.

467. **Thermomechanics of Nuclear Reactor Systems.** Same as Nuclear Engineering 467. Origin of thermomechanics problems in nuclear reactor systems; heat generation and transfer in nuclear power systems; thermal stress in nuclear reactor systems; dynamical theory including effects of thermal-shock and thermal stress-wave propagation; current thermomechanics problems in nuclear reactor design. Term paper required. I, 1 unit. Prerequisite: Nuclear Engineering 401 or consent of instructor.

URBAN PLANNING AND LANDSCAPE ARCHITECTURE

376. **Planning Analysis.** Research and analytic techniques in urban planning; economic base and employment, population, market analysis; derivation and use of statistical data. ½ unit. Prerequisite: Consent of instructor.

377. **Comprehensive Planning Procedure.** Design and plan-making techniques in urban planning; land use, circulation and community facilities; the development of the comprehensive general plan. ½ unit. Prerequisite: Consent of instructor.

488. **Urban Planning Research.** Individual and group instruction in the application of professional competences in urban planning to the analysis of urban development problems and to the formulation of approaches to solution of such problems. ½ to 2 units. Prerequisite: Consent of instructor.

Suggested Programs for the Master's Degree

From the courses offered in civil engineering and in other departments,

the student may select a variety of programs of study. He is assisted by his adviser in selecting courses which complete his background of fundamental work and which advance his knowledge in one of the fields of specialization in the department.

The following programs are presented as examples to help the student to evaluate the possibilities of programs in specific fields. The programs given are for full-time graduate students. Research or teaching assistants normally follow half-time programs and cover the same material as full-time students but at the rate of two and one-half to three units each semester for their two years of study.

Study beyond the degree of Master of Science is an entirely individual matter, and each program is carefully reviewed and selected by the student and his adviser.

CONSTRUCTION ENGINEERING AND MANAGEMENT

A typical construction engineering and management program, but one which may be modified to suit the needs of a particular candidate, is shown for two semesters. Prerequisite requirements include Mathematics 345 (Differential Equations); Civil Engineering 215 (Construction and Engineering Economy); Mathematics 263 (Statistics in Engineering and Physical Sciences); or the equivalent.

First Semester	**Units**
C.E. 315 Construction Productivity	½
C.E. 316 Construction Planning	½
C.E. 391 Numerical and Computer Applications in Civil Engineering	1
Math. 315 Matrix Algebra	1
[1]C.E. 499 M Thesis	1
	4

Second Semester	**Units**
C.E. 318 Construction Costs, Estimates, and Control	½
Math. 363 Advanced Statistics	1
C.E. 416 Design of Construction and Industrial Operations	1
[1]C.E. 499 M Thesis	1½
	4

HIGHWAY ENGINEERING

A wide range of courses is available to the student leading either to general study of highway engineering or to some specialization in the areas of highway drainage, geometrics and location, materials, pavements, soils, traffic, or highway management. A full program in traffic engineering is outlined under that heading.

[1] The 2½ thesis units may be replaced by 3½ units of electives.

A well-balanced program includes one or more courses from four or five of the areas listed below:

1. Advanced mathematics (Mathematics 363, Statistics, is recommended; other suggestions are Mathematics 343 and 345).
2. Theoretical and applied mechanics (Theoretical and Applied Mechanics 416, 451, and 462).
3. Materials, pavement analysis and design (Civil Engineering 321, 420, 421, 473; Theoretical and Applied Mechanics 424, 427).
4. Geometrics and traffic (Civil Engineering 325, 426, 427, 428).
5. Soils (Civil Engineering 383, 384, 385, 482, 483, 485).
6. Highway management (see suggested topics for Civil Engineering 497).
7. Highway design, drainage, and special problems (Civil Engineering 322, 456, 497).

A student may complete his program with other courses in physics, chemistry, or geology.

A possible program for the general study of highway engineering might be as follows:

First Semester		**Units**
C.E. 321	Bituminous Materials and Mix Design	½
C.E. 322	Development of Highway Facilities	1
C.E. 325	Highway Traffic Characteristics	½
C.E. 385	Engineering Aspects of Surficial Soils	1
C.E. 420	Pavement Design, I	1
C.E. 426	Traffic Planning	1
C.E. 495	Highway and Traffic Seminar	0
		5

Second Semester		**Units**
C.E. 421	Pavement Design, II	1
C.E. 427	Geometric Highway Design	1
C.E. 456	Hydraulics of Surface Drainage	1
C.E. 485	Soil Engineering for Transportation Facilities	1
C.E. 495	Highway and Traffic Seminar	0
		4

GEODETIC AND PHOTOGRAMMETRIC ENGINEERING

First Semester		**Units**
C.E. 391	Numerical and Computer Applications in Civil Engineering	½ to 1
C.E. 401	Geodetic Engineering	1
C.E. 403	Photogrammetry	1
C.E. 497	Special Problems	½
Geog. 373	Map Compilation and Construction	1
		4½

Second Semester		**Units**
C.E. 402	Geodetic Engineering	1
C.E. 404	Photogrammetry	1

C.E. 497 Special Problems	½
Geog. 473 Problems in Cartography	1
Math. 363 Advanced Statistics	1
	4½

HYDRAULIC ENGINEERING

Graduate courses in hydraulic engineering are available to the student leading to specialization in the following major areas: hydromechanics, hydraulic structures, hydrology, and water resources. The recommended programs emphasize training on certain basic subjects and yet provide flexibility to develop a well-balanced curriculum for each student to meet the need for his background, interest, and ability. Two programs leading to a master's degree are as follows:

Hydromechanics and Hydraulic Structures

First Semester	**Units**
C.E. 351 Hydromechanics or T.A.M. 335 Dynamics of Fluids	¾
C.E. 353 Hydraulic Structures	¾
C.E. 450 Advanced Hydrologic Analysis and Design	1
C.E. 495 Hydraulic Engineering Seminar	0
C.E. 497 Special Problems	½ to 1
Approved Electives	1
	4 to 4½

Second Semester	**Units**
C.E. 354 Hydraulic Engineering Laboratory	¾
C.E. 458 Open-Channel Hydraulics	1
C.E. 495 Hydraulic Engineering Seminar	0
Approved Electives	2¾ to 3¼
	4½ to 5

The course C.E. 351 may be replaced by T.A.M. 335 — Dynamics of Fluids, if necessary. The student must take at least 3¾ to 4¼ units of technical electives in order to make up a minimum of nine units required for a master's degree. Two of the technical electives, each not less than ¾ unit, must be in the fields of structures and soil mechanics.

Hydrology and Water Resources

First Semester	**Units**
C.E. 351 Hydromechanics	¾
C.E. 450 Advanced Hydrologic Analysis and Design	1
C.E. 495 Hydraulic Engineering Seminar	0
C.E. 497 Special Problems	½ to 1
Approved Electives	1¼ to 2¼
	4 to 4½

Second Semester		Units
C.E. 352	Water Resources Design	¾
C.E. 458	Open-Channel Hydraulics	1
C.E. 495	Hydraulic Engineering Seminar	0
	Approved Electives	2¾ to 3¼
		4½ to 5

The student must take at least 4 to 5½ units of technical electives in order to make up a minimum of nine units required for a master's degree. Two of the technical electives, each not less than ¾ unit, should be in the fields of sanitary engineering and statistics. Other possible electives in addition to civil engineering courses include work in ground water geology, economics, and mathematics.

RAILWAY ENGINEERING

Students electing this program are expected to have a preparation in differential equations and computer programming. Lacking this, the preparation must be secured in addition to the suggested nine units.

First Semester		Units
C.E. 333	Urban and Regional Transportation, or approved elective	1
C.E. 383	Soil Mechanics	1
*C.E. 435	Railway Construction and Maintenance	1
C.E. 497	Special Problems, or C.E. 499 Thesis Research	½
Econ. 484	Economics of Transportation	1
		4½

* Students not adequately prepared for this course are required to take Civil Engineering 335 for ½ unit as a prerequisite (or concurrently).

Second Semester		Units
C.E. 338	Terminals	1
C.E. 391	Numerical and Computer Applications in Civil Engineering	1
*C.E. 436	Railroad Location and Operation	1
C.E. 485	Soil Engineering for Transportation Facilities, or Econ. 485 Economics of Transportation	1
C.E. 497	Special Problems, or C.E. 499 Thesis Research	½
		4½

* Students not adequately prepared for this course are required to take Civil Engineering 336 for ½ unit as a prerequisite (or concurrently).

GENERAL TRANSPORTATION

Students electing the transportation program are expected to have a preparation in differential equations and computer programming. Lacking this, the preparation must be secured in addition to the suggested nine units.

First Semester		Units
C.E. 333	Urban and Regional Transportation	1
C.E. 497	Special Problems: Transportation Planning	1
C.E. 497	Special Problems, or C.P. 372 Theory and Practice, or approved elective	1
C.E. 499	Thesis Research	½
Econ. 484	Economics of Transportation	1
		4½

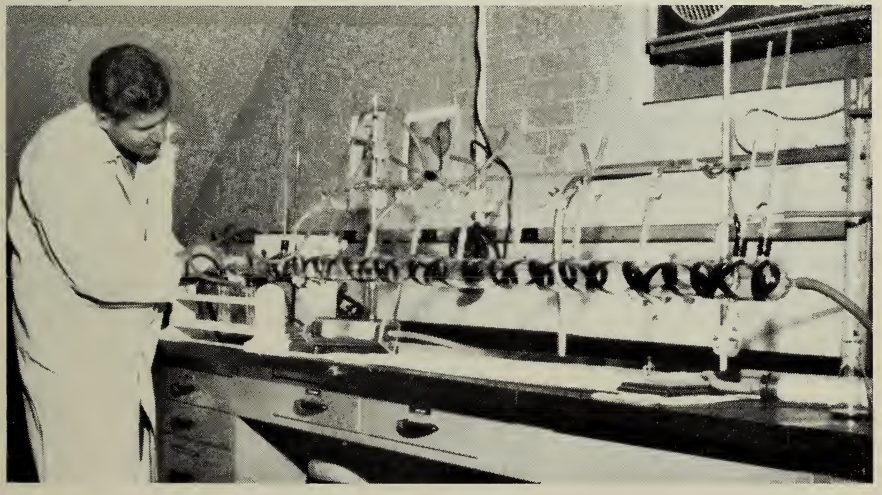
Second Semester		Units
C.E. 334	Airport Design, C.E. 436 Railroad Location and Operation, or, C.E. 325 Highway Traffic Characteristics	½ to 1
C.E. 338	Terminals	1
C.E. 497	Special Problems: Transportation Planning	1 to 1½
C.E. 499	Thesis Research	½
Econ. 485	Economics of Transportation	1
		4½

SANITARY ENGINEERING

Proper selection of electives provides the student the option of either a broad program in sanitary engineering or concentration in one of three special areas; namely, water and waste water treatment, radiological health, or air pollution.

First Semester		Units
C.E. 345	Public Health Engineering	½
C.E. 440	Theory of Water Treatment	1

This research equipment was used to study the viability of bacteria in connection with airborne contaminants in hospitals.



Sanitary Engineering Laboratory Course	1
Biology Course	1
Approved Electives, or C.E. 499 Thesis Research	1
	4½

Second Semester	Units
C.E. 442	1
C.E. 499 Thesis Research, or C.E. 497 Special Problems	1
Approved Electives	2½
	4½

Other Courses. Approved elective may be selected from suitable courses in sanitary and civil engineering, microbiology, chemistry, mathematics, nuclear engineering, physics, physiology, and fluid mechanics.

SOIL MECHANICS

SOIL MECHANICS AND FOUNDATIONS

First Semester	Units
C.E. 383 Soil Mechanics	1
C.E. 385 Engineering Aspects of Surficial Soils	1
C.E. 460 Structural Analysis, or C.E. 461 Structural Theory and Design	1
C.E. 481 Earth Dams and Related Problems	1
Geol. 450 Geology for Civil Engineers	1
	5

Second Semester	Units
C.E. 384 Applied Soil Mechanics	1
C.E. 480 Earth Pressures and Retaining Structures	1
C.E. 482 Measurement of Soil Properties	1
C.E. 484 Foundation Engineering	1
	4

STRUCTURES AND FOUNDATIONS

First Semester	Units
C.E. 383 Soil Mechanics	1
C.E. 461 Structural Theory and Design	1
C.E. 481 Earth Dams and Related Problems	1
Geol. 450 Geology for Civil Engineers	1
Selected Course	0 to 1
	4 to 5

Second Semester	Units
C.E. 384 Applied Soil Mechanics	1
C.E. 462 Structural Theory and Design	1
C.E. 465 Structural Design in Metals	1

C.E. 480	Earth Pressures and Retaining Structures	1
C.E. 484	Foundation Engineering	1
		5

Other Courses. Special Problems in Soil Mechanics, Rock Mechanics, and Structures or other courses in these and related fields may be substituted in the above programs according to the student's previous work and the objectives of his study.

STRUCTURAL ENGINEERING

A wide range of courses is available in this field, leading to specialization in reinforced concrete, structural metals, theory and analysis, structural and soil dynamics, and other areas. The student selects four to five units of course credits each semester, during the two or more semesters of his career, after consultation with his adviser. A course in differential equations is a prerequisite for work in structural engineering. A well-balanced program ordinarily includes one or more units from at least four of the six following groups of courses:

1. Advanced mathematics (Mathematics 315, 343, 346, 382, 387, 388).
2. Advanced mechanics (Theoretical and Applied Mechanics 416, 441, 451, 464).
3. Structural analysis (Civil Engineering 461, 471, 472, 473, 474).
4. Structural design (Civil Engineering 464, 465, 468, 477, 369).
5. Behavior of structures (Civil Engineering 467, 475, 366; Theoretical and Applied Mechanics 424).
6. Soil mechanics and foundation engineering (Civil Engineering 480 to 485, 383, 384).

The student may round out his program with other courses in civil engineering, theoretical and applied mechanics, mathematics, or physics (especially Physics 383).

Because of the wide selection of courses specific programs are not suggested here. The student is encouraged to take some courses in areas other than his specialty to provide greater depth in his program.

TRAFFIC ENGINEERING

First Semester		Units
C.E. 325	Highway Traffic Characteristics	½
C.E. 420	Pavement Design, I	1
C.E. 426	Traffic Planning	1
C.E. 495	Highway and Traffic Seminar	0
C.E. 499	Thesis Research	1
Soc. 385	Social Statistics	1
		4½

Second Semester		Units
C.E. 427	Geometric Highway Design	1
C.E. 428	Traffic Engineering Operations	1
C.E. 495	Highway and Traffic Seminar	0
C.E. 497	Special Problems	1
C.E. 499	Thesis Research	1
		4

Other Courses. Work in special problems listed under Civil Engineering 497, Highway and Traffic Engineering, and Urban Planning 376 and 377, may be substituted for certain of the courses suggested above.

URBAN PLANNING AND MANAGEMENT

With almost 80 per cent of the steadily increasing population in the United States living in urban areas there is a growing concern at all levels of government, from local to federal, with the many problems created by this urban growth. Civil engineers are directly and intimately concerned with the physical facilities that make up the urban complex and they are becoming involved in many ways in the planning and management of the urban community. As municipal engineers, public works directors, and city managers, civil engineers need a broad background of advanced training not only in civil engineering, but in many other disciplines which influence their decisions.

The variety of courses offered by these other disciplines at the University of Illinois provides an excellent opportunity for graduate study by civil engineering students interested also in urban planning and management. Because of the variety of combinations possible, specific programs of courses are not listed.

ENGINEER OFFICERS PROGRAMS

A number of special programs for officers in the Air Force, Army Corps of Engineers, and Navy Civil Engineering Corps are available. These programs are designed to meet the particular needs of the different services. Because of the wide variety of courses that are offered, the programs can be tailored to suit the backgrounds, capabilities, and interests of each student officer.

The basic course is one of twelve months duration which includes advanced work in a broad range of civil engineering study. Other programs, from eighteen to twenty-four months duration, provide for greater specialization in such fields as structural dynamics, systems analysis (construction engineering, operations research), urban and regional planning, engineering physics, nuclear engineering, and water resources. While all of these special

programs include a core of required courses which differs among the several programs, they possess sufficient flexibility, through electives, to permit the development of programs that are compatible with the needs and interests of both the student officers and the Department of Defense services that they represent. Detailed suggested programs may be obtained from the Head of the Department.

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Department of Civil Engineering
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Urbana, Illinois 61803

Housing Division
420 Student Services Building
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Office of Foreign Student Affairs
310 Student Services Building
Champaign, Illinois 61822

University offices are open Monday through Friday
from 8:00 a.m. to 12:00 noon and
from 1:00 to 5:00 p.m. except on holidays.

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